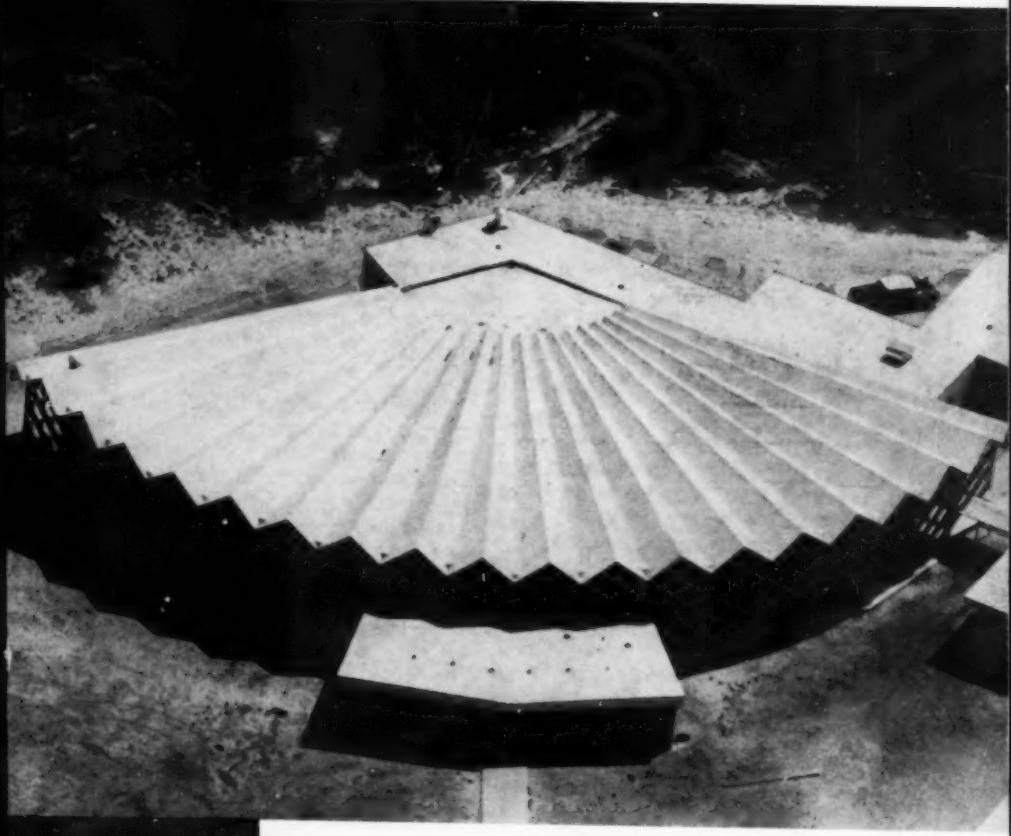
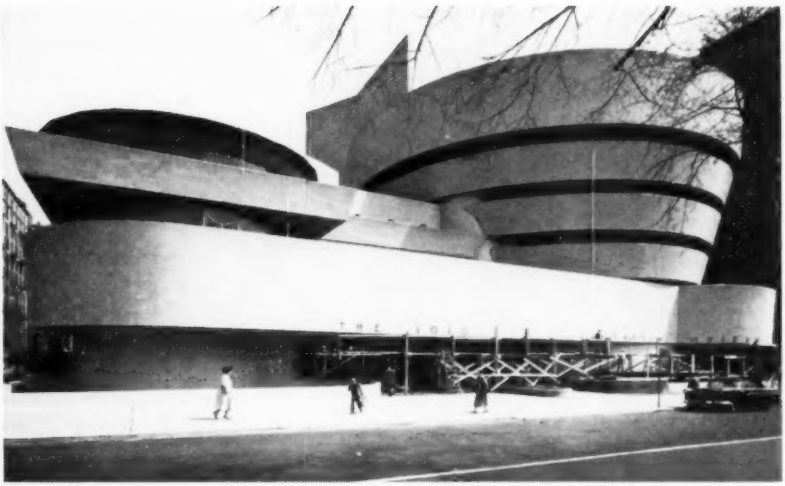
JOURNAL
OF THE AMERICAN CONCRETE INSTITUTE



Quarterly Discussion
Starts on p. 905



A Work of Art for Works of Art . . .

• To anyone who appreciates fine craftsmanship in concrete, one fact stands out about Frank Lloyd Wright's Guggenheim Museum in New York: it is a genuine work of structural art which demanded exceptional precision, patience, and perseverance by the contractor. Only great dedication could have solved the many problems that arose during construction.

Utter precision in formwork and concreting resulted in smooth surfaces, true curves and sharp corners that are worthy of the greatness of the project, its contents, and its architect.

Lone Star is proud to have supplied all of the portland cement required for this significant structure—a dramatic example of the beauty and limitless versatility of modern concrete in the hands of imaginative designers and skilled, resourceful builders.

LONE STAR CEMENT CORPORATION

Offices: ABILENE, TEX. · ALBANY, N. Y. · BETHLEHEM, PA. · BIRMINGHAM · BOSTON · CHICAGO · DALLAS · HOUSTON · INDIANAPOLIS
KANSAS CITY, MO. · LAKE CHARLES, LA. · NEW ORLEANS · NEW YORK · NORFOLK · RICHMOND · SEATTLE · WASHINGTON, D. C.

LONE STAR CEMENT, WITH ITS SUBSIDIARIES, IS ONE OF THE WORLD'S LARGEST CEMENT PRODUCERS, 21 MODERN MILLS, 49,100,000 BARRELS ANNUAL CAPACITY

MARCH, 1960

No. 9

V. 31

Proceedings V. 56

Cost per copy $1.50. Extra copies to ACI members $1.00.

Papers, committee reports, and other contributions to the **Proceedings** pages of this Journal, as submitted in furtherance of Institute objectives, are, if published, accepted on the sole responsibility of their authors. Institute authority attaches only to standards adopted as provided in the Bylaws.

Advertising. See statement under "Alphabetical List of Advertisers," final page **News Letter section.**

Membership dues and Journal subscription rates. Members receive the Journal as one of the considerations of dues payment. Membership grades are: Individual (U.S., its possessions, and North and Central America), $20; Individual (all other foreign countries), $16; Corporation, $65; Contributing, $135; Junior, $10.00; Student, $5. Subscription price is $18 per year, payable in advance. The Journal is issued monthly, July to June (the volume year being completed by title page, contents, indexes, and closing discussion in Part 2 of the subsequent September and December issues).

Bound volumes 1 to 54 of PROCEEDINGS of the AMERICAN CONCRETE INSTITUTE (1905 to 1958) are for sale as far as available at prices to be had on inquiry of the Secretary-Treasurer. Special prices apply for members ordering bound volumes in addition to the monthly Journal.

Copyright ©, 1960, American Concrete Institute. Printed in U.S.A.

Publication office: P.O. Box 324, Shepherdsville, Ky. Entered in the Post Office at Shepherdsville, Ky., as mail of the second class.

Editorial and advertising departments at ACI headquarters, P.O. Box 4754, Redford Station, Detroit 19, Mich.

JOURNAL
of the
AMERICAN CONCRETE INSTITUTE

Published by the American Concrete Institute under the authority of its Board of Direction

President
PHIL M. FERGUSON

Vice-Presidents
JOE W. KELLY
LEWIS H. TUTHILL

Directors

ARSHAM AMIRIKIAN	ROBERT C. JOHNSON
WILLIAM H. ARMSTRONG	BRYANT MATHER
S. J. CHAMBERLIN	WALTER J. McCOY
ROGER H. CORBETTA	RAYMOND C. REESE
GEORGE C. ERNST	C. D. WAILES, JR.
E. A. FINNEY	CEDRIC WILLSON

Past Presidents
FRANK KEREKES
WALTER H. PRICE
DOUGLAS McHENRY

Secretary-Treasurer
WILLIAM A. MAPLES

Technical Director
KENNETH D. CUMMINS

Managing Editor
ROBERT E. WILDE

Advertising Manager
THOMAS C. AKAS

Manager, Publication Sales
ISABELLE DAVIS

Membership Secretary
EVELYN SCHLITZ

the ACI JOURNAL

is edited by the Secretary of the Technical Activities Committee under the direction of the Committee

WALTER J. McCOY
Chairman

PHIL M. FERGUSON
(ex officio)

WILLIAM A. MAPLES
Secretary

G. E. BURNETT

E. A. FINNEY

CLYDE E. KESLER

BRYANT MATHER

MICHAEL PREGNOFF

J. J. SHIDELER

WILLIAM A. MAPLES
Editor

ROBERT E. WILDE
Managing Editor

ROBERT G. WIEDYKE
Associate Editor

RICHARD A. MEHOKE
Assistant Editor

MARIAN PATTEN
Editorial Assistant

RUTH GABLE
Editorial Secretary

Coming next month in the JOURNAL

ACI COMMITTEE 609 report on "Consolidation of Concrete" opens the April issue. The report reviews techniques and equipment for consolidating concrete, up-dating previous data published on this subject.

•

A. C. SCORDELIS presents a research paper on "Internal Forces in Uniformly Loaded Helicoidal Girders."

•

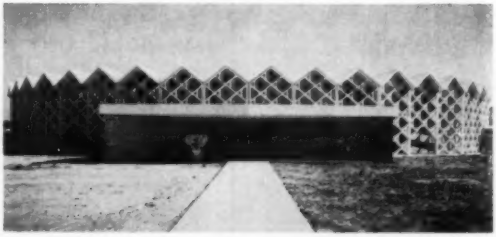
N. STUTTERHEIM discusses "Some Properties and Uses of High-Magnesia Portland Blast-Furnace Slag Cement Concretes."

•

"Reinforced Concrete and Prestressed Pipes as Electrical Pylons" is a design presentation by E. WOLMAN.

•

A. SIEV thoroughly discusses the "Design of Unsymmetrical Reinforced Concrete Sections."



On the Cover—Jewish Synagogue of St. Petersburg, Fla. The fan-shaped folded plate roof and precast sunscreen are of lightweight concrete. Architect: Frank A. Bonsey, St. Petersburg. Structural engineer: Joseph C. Russello, Tampa. General contractor: R. M. Thompson Co., St. Petersburg. The sunscreens were precast by Florida Cast Stone Co., Tampa; General Materials, Inc., St. Petersburg, supplied the ready-mixed concrete.—Photos courtesy "Concrete Facts," Expanded Shale, Clay and Slate Institute

Manuscripts of papers, discussions, and reports should be sent in triplicate to:

Secretary, Technical Activities Committee
AMERICAN CONCRETE INSTITUTE
P. O. BOX 4754, REDFORD STATION, DETROIT 19, MICHIGAN

Title No. 56-45

Long-Time Study of Cement Performance in Concrete

Chapter 12-Concrete Exposed to Sea Water and Fresh Water

By I. L. TYLER

During 1941 and 1942 four experimental installations of test piling were driven, three in sea water and one in fresh water, for studies of concrete performance. One sea water exposure was in the east mooring basin of Cape Cod Canal, so as to evaluate the effect of exposure in a cold climate. A fresh water exposure in similar climate was constructed at the confluence of Esopus Creek and the Hudson River at Saugerties, N. Y. Two other sea water exposures were in the mild climates of Florida and southern California. Twenty-two of the 27 Long-Time Study cements were used in the three eastern exposures; seven were used in California. After more than 15 years, significant trends in performance are developing, not all of them along the anticipated lines of the investigation of cement performance but still of much more than casual interest to users of concrete in marine construction.

■ THE PURPOSE OF THE LONG-TIME STUDY investigation was to study the performance of the five principal ASTM cement types under most of the conditions of exposure frequently encountered. Chapter 12 covers a phase of this investigation concerned with durability of concrete in marine construction in mild and severe climates, in sea water and in fresh water, subjected to daily tidal fluctuations. This phase of the study presents one of the few opportunities for direct comparisons of cement performance in marine construction with cements covering wide ranges in chemical composition.

Four sites, representing a wide range in exposure conditions, were selected for the pile installations. The first (Project 8A) was in the east mooring basin of the Cape Cod Canal having a normal tidal range of about 9 ft in a climate of subfreezing weather in winter with exposure to sea water. The second (Project 8B) was in Esopus Creek at its confluence with the Hudson River at Saugerties, N. Y. Here the exposure was supposedly to fresh water having a tidal range of about 4 ft. The climate is similar to that at the Cape Cod Canal. The third (Project 8C) was constructed in the mild climate of Florida at Salt Run near St.

I. L. Tyler, manager, Field Research Section, Portland Cement Association Research and Development Laboratories, Skokie, Ill., joined PCA in 1941 and has been concerned mainly with performance of concrete structures. This assignment includes in part the study of unusual problems as they are found in the field; it includes long-range investigations of which the Long-Time Study of Cement Performance in Concrete is a major component. An ACI member, he has been active on many Institute committees, including chairmanship of several, on such subjects as inspection, mass concrete, hot weather concreting, proportioning, and aggregates. Prior to joining PCA he was responsible for materials testing, inspection, and mix proportioning on various hydroelectric power projects.

Augustine. Salt Run is a body of sea water connecting with the Atlantic Ocean, having a tidal range of about 4 ft. The fourth installation (Project 8D) was in Newport Bay at Corona del Mar, Calif., in an arm of the bay connecting with the Pacific Ocean adequately protected by breakwaters. The tidal range is about 4 ft. Climatic conditions at the Florida and California exposures are similar; freezing is not a consideration.

Twenty-two of the 27 cements manufactured for the Long-Time Study were included in the piling investigation, one or more from each of the five ASTM types. Three were air-entraining cements. Table 1 lists the cements, potential composition of each, and a partial listing of oxide compositions. A letter (T) denotes an air-entraining cement, originally called a "treated cement," ground from clinker with flake vinsol resin added.

The three East Coast installations (Projects 8A, 8B, and 8C) used all 22 of the cements listed. The piles at Corona del Mar (Project 8D) had seven cements embracing a wide range in composition but without air entrainment.

Three combinations of aggregates were used for the test piles. For the installation at Cape Cod Canal and that at Saugerties, N. Y., natural sand and gravel were from the Plainfield, Ill., deposit. For the St. Augustine installation, Dawes sand from Trudy, Ga., and Montgomery gravel from Montgomery, Ala., materials commonly available at the construction site, were used to construct the piles. For the Corona del Mar piles the aggregates were natural sand and crushed gravel from the Sierra deposit, San Gabriel Canyon near Los Angeles. Maximum size of coarse aggregate was about 1 in. in each case. All aggregates were considered to be of excellent quality, though the Montgomery gravel has since come under suspicion as potentially alkali reactive.

Three piles were made with each cement used at each project as follows:

Mix 1—5 sacks per cu yd, 2 in. slump, consolidated by internal vibration
Mix 2—7 sacks per cu yd, 2 in. slump, consolidated by internal vibration
Mix 3—7 sacks per cu yd, 8 in. slump, manually spaded into place

These mixes resulted in water-cement ratios of a little less than 7, 5, and 6 gal. per sack, respectively, for the non-air-entraining cements, with a further reduction of about ¼ gal. per sack for the air-entrained mixes.

All piles were 12 in. square in cross section with 1-in. chamfered corners, tapered at one end to 7½ in. square for driving. Length depended on depth of water and penetration required; 30 ft at Cape Cod, 20 ft at Saugerties, 30 ft at St. Augustine, and an average of about 20 ft at Corona del Mar.

For the three Eastern exposures, the piles were reinforced by eight ⅝-in. round mild steel bars wired into square cages with ¼-in. round tie bars spaced 3 ft apart. Four ⅝-in. round bars, lapped to provide extra strength at the midlength during handling, were used at Corona del Mar. The concrete cover over the reinforcing steel was 1½ in. in all cases.

Concrete was placed in oiled plywood forms with reinforcing cages suspended in position. Removable wedges held the cages in position during casting. Celotex form lining was used for one side of the piles containing Mix 3 (7 sack, 8 in. slump) for Cape Cod and for Saugerties, but not for the other two exposures.

Piles for Cape Cod and Saugerties were fabricated in Chicago and shipped to their destinations by rail. Those for St. Augustine were made in Jacksonville, Fla., and shipped to the exposure site by barge. For the Corona del Mar installation, the piles were fabricated in Los An-

TABLE 1—CEMENTS—POTENTIAL COMPOSITION AND MINOR OXIDES

Cement No.	Calculated compound, percent by weight				From chemical analyses, percent by weight				
	C_3S	C_2S	C_3A	C_4AF	SO_3	Free CaO	MgO	Na_2O	K_2O
11	54.5	18.4	10.9	7.2	1.59	0.43	3.58	0.22	0.56
12	48.9	24.6	11.2	7.3	1.55	0.11	3.11	0.32	0.43
13	53.6	23.2	8.9	6.4	1.62	1.61	1.07	0.02	0.20
14	47.1	28.1	7.1	9.2	1.73	0.19	2.37	0.03	1.40
15	72.0	3.9	9.9	7.5	1.92	0.44	0.71	0.07	0.25
16	56.2	18.9	6.4	10.7	1.71	0.73	1.92	0.25	0.46
18	48.2	24.9	12.2	6.8	1.83	0.33	2.13	0.15	0.14
21	45.4	33.7	5.1	9.8	1.24	0.65	1.18	0.23	0.44
22	45.0	30.5	5.4	11.7	1.41	0.65	3.10	0.24	0.39
23	56.4	18.9	2.1	16.6	1.50	0.43	0.85	0.61	0.14
24	43.9	26.6	4.4	14.8	1.75	0.88	3.07	0.03	1.33
25	37.5	36.5	3.8	14.8	1.86	0.21	2.24	0.21	0.60
31	60.1	13.0	9.6	6.4	2.23	1.45	3.20	0.26	0.26
33	63.2	9.8	9.2	7.7	2.31	1.83	1.38	0.24	0.46
41	23.5	48.1	3.4	15.2	1.98	0.44	2.72	0.03	1.22
42	29.5	53.0	2.7	8.2	1.52	0.21	1.84	0.14	0.29
43	29.5	45.2	4.8	12.8	1.97	0.12	1.48	1.06	0.10
43A	32.4	48.2	3.9	9.3	1.87	0.35	0.99	0.35	0.01
51	45.4	35.8	2.2	10.0	1.40	0.54	1.64	0.07	0.27
12T	49.1	24.8	11.1	7.1	1.54	0.12	3.07	0.32	0.41
16T	54.4	20.2	6.8	10.4	1.84	0.75	2.01	0.25	0.46
21T	41.9	37.2	5.4	9.8	1.27	0.60	1.28	0.24	0.45

SiO_2 — corrected by subtracting two-thirds of the insoluble residue from SiO_2 as determined.
Al_2O_3 — corrected by subtracting one-third of the insoluble residue, the R_2O_3 and TiO_2 from Al_2O_3 as determined.
CaO — corrected by subtracting free CaO from CaO as determined.

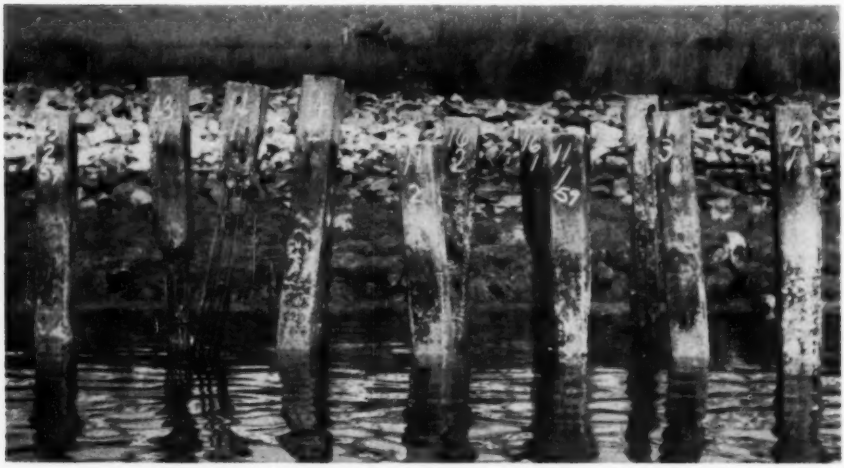


Fig. 1—A portion of the test piles in Cape Cod Canal

geles and shipped by truck and barge to the exposure site. All specimens were kept moist from the time they were made until installation, except in a few cases for short intervals during shipment. The piles for Saugerties had nearly 1 year storage under wet earth before installation.

Except for the Saugerties installation, the piles were jetted into position using the dead weight of a pile hammer to help sink the pile to the desired penetration when necessary. At the Saugerties installation the piles were held vertically in position in a previously excavated depression in Esopus Creek, then backfilled to river-bottom level to hold them permanently in position. In spite of all precautions, a few piles were superficially damaged at the top during installation.

The sixty-six 30-ft piles installed in the Cape Cod Canal in the fall of 1941 had to be relocated in 1944 and 1945 because shifting sands at the east end of the east mooring basin where the installation was first made had deepened the channel at this point sufficiently to remove support and cause overturning of a number of the piles. Fourteen overturned piles were recovered by diving operations; those that remained upright were withdrawn and the installation was relocated east of the original installation near the north canal bank, which was relatively free from eroding currents. While the relocation is an unusual occurrence for test specimens, it is believed that there was no damage to the piles except in one instance. Pile No. 31-3 was accidentally dropped and broken near its midlength. This pile has been exposed on the canal bank riprap since but is not considered in performance of the installation.

PERFORMANCE OF THE SPECIMENS

At Cape Cod Canal

Early in the exposure of the piles in Cape Cod Canal it became evident that rusting of the steel reinforcing was causing serious damage to the specimens because of the resulting expansion. Cracking of concrete over the reinforcing steel accompanied deterioration due to weathering to such an extent that a true evaluation of concrete performance was made most difficult.

In the tables that follow, no attempt has been made to separate effects of steel corrosion and the effects of weathering. A system of ratings has been developed for the two severe exposures. Visual observations of the amount of deteriorated and eroded concrete supplies the basis for determining the rating, with (1) denoting a perfect (undamaged) specimen and (10) denoting complete deterioration so far as a useful structural member is concerned.

Table 2 shows the condition of the specimens after 17 years of exposure at Cape Cod Canal. Fig. 1 shows a small portion of the installation.

From knowledge of the project and from the data shown in Table 2, the following statements seem to be justified. They are of interest almost as much from what they fail to show as from the positive information developed.

TABLE 2—CONDITION RATINGS OF TEST PILES IN CAPE COD CANAL, 1958*

Cement No.	Mix 1, 5 sack, 2 in. slump	Mix 2, 7 sack, 2 in. slump	Mix 3, 7 sack, 8 in. slump
11	9	2	5
12	5	1	4
13	10	2	6
14	10	2	6
15	10	1	3
16	8	5	4
18	10	2	5
21	10	2	5
22	4	5	3
23	9	2	3
24	10	4	6
25	3	2	2
31	6	4	broken
33	6	3	5
41	5	1	1
42	10	1	3
43	10	3	1
43A	2	1	1
51	6	3	4
12T	5	2	4
16T	1	1	2
21T	1	1	2

*In which (1) denotes a near perfect specimen and (10) complete deterioration so far as a useful structural member is concerned.

TABLE 3—CONDITION RATINGS OF TEST PILES AT SAUGERTIES, N. Y., 1958*

Cement No.	Mix 1, 5 sack, 2 in. slump	Mix 2, 7 sack, 2 in. slump	Mix 3, 7 sack, 8 in. slump
11	2	2	3
12	4	1	2
13	3	2	2
14	5	2	2
15	5	1	2
16	2	2	2
18	2	2	2
21	4	1	2
22	4	2	2
23	2	2	2
24	7	1	2
25	2	2	2
31	5	2	4
33	6	3	6
41	2	2	2
42	1	2	1
43	2	1	2
43A	2	2	2
51	3	1	2
12T	2	1	2
16T	2	1	3
21T	2	1	2

*In which a rating of (1) denotes a nearly perfect specimen and (10) complete deterioration so far as a useful structural member is concerned.

1. Cover over the reinforcing steel (nominally 1½ in.) was insufficient to prevent rusting of reinforcement and cracking of adjacent concrete. In many cases the cracking at least partially obscured weathering effects.

2. Deterioration and cracking was most severe on the 5-sack, 2-in. slump specimens; least on the 7-sack, 2-in. slump specimens.

3. Among the non-air-entrained specimens, cement composition appears to be of minor consequence, with the Type IV cements having slightly the best average performance in the two rich mixes.

4. The beneficial effects of air entrainment are shown, though by no means are they so clear-cut as on most other projects of the Long-Time Study. Of nine direct comparisons that can be made, six are favorable to air entrainment, two show no improvement, and one is unfavorable.

5. No consistent effect of the absorptive form liner on resistance to weathering could be noted.

At Saugerties, N. Y.

At this project, sixty-six 20-ft piles were installed in 1942 in Esopus Creek near its confluence with the Hudson River in what was supposed to be fresh water with no abnormal contamination and with a tidal range averaging 4 ft. Deterioration in the specimens was first detected in 1952 by soniscope tests. Pulse velocity measurements made at that time indicated differences of as much as 5000 ft per sec between the concrete at the tops of specimens (assumed to be unaffected) and that at midtide level. Within the next year or two visual evidence of deterioration began to appear near low tide level in the form of deep etching and ravelling of the concrete. Since 1952 pulse velocities through the concrete below high tide level have decreased measurably and surfaces have deteriorated to the conditions shown in Table 3. Since

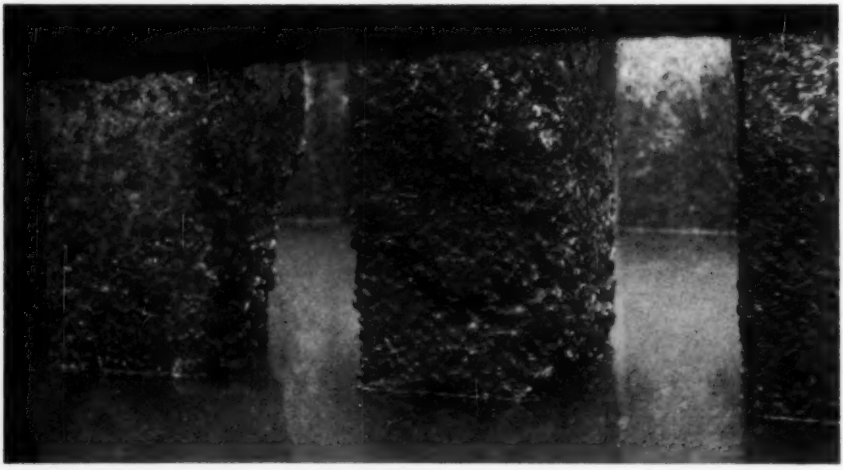


Fig. 2—Damaged surfaces on test piles at Saugerties, N.Y.

deterioration is most severe below the low tide level, it has been assumed that freezing and thawing is not a major factor in deterioration. Fig. 2 shows severely damaged surfaces near low tide level.

Instead of being fresh water, as had been assumed, Esopus Creek was contaminated for 3 or 4 years during the war by an estimated 400 tons of "white water" per day which was discharged from an obsolete paper mill that had been temporarily reactivated and was situated only a short distance above the pile installation and on the same bank of the creek. During low flows of the creek, the tidal action caused the mixture of normal stream water and "white water" of unknown acid content, to move back and forth past the pile installation. The "white water," estimated to have a sulfuric acid concentration corresponding to a pH of 4 or 5, could well have caused the type of deterioration found on this project or at least have contributed substantially to it, even though the concentration of acid in the river water adjacent to the test piles must have been materially below that discharged into the stream from the paper mill.

As at Cape Cod, little or no effect of composition of cements is shown. Air entrainment shows a negligible effect so far as can be ascertained. Only the water-cement ratio (richness of mix) seems to be of great significance in this project, the rich dry mix (7 sack, 2 in. slump) being considerably better in performance than the other two (7 sack, 8 in. slump and 5 sack, 2 in. slump). Absorptive form liner, used on one face of the 7-sack, 8-in. slump specimens, has not changed performance appreciably.

From this test project the following conclusions may be drawn:

1. As at Cape Cod, cover over the reinforcing steel is shown to be inadequate, though in this case the cracking over the reinforcement is less conspicuous than at Cape Cod Canal or at the other salt water exposures.

2. Deterioration was most severe in the 5-sack, 2-in. slump specimens and least in the 7-sack, 2-in. slump specimens.

3. Effects of cement composition were minor or nonexistent.

4. Effects of air entrainment were minor but on the average slightly favorable.

At Salt Run near St. Augustine, Fla.

The installation was made in December, 1941. In this exposure to sea water in a mild climate, the main feature is cracking of the concrete over reinforcing steel. As shown by Table 4, the effect of mix proportions is obvious and there is some improvement due to air entrainment. In this table the lineal feet of cracking parallel to the reinforcing steel is shown instead of specimen rating. Typical cracking and rust staining over the reinforcing steel is shown in Fig. 3.

Here, for the first time in any of the sea water exposures, effects of cement composition are beginning to emerge, though developments

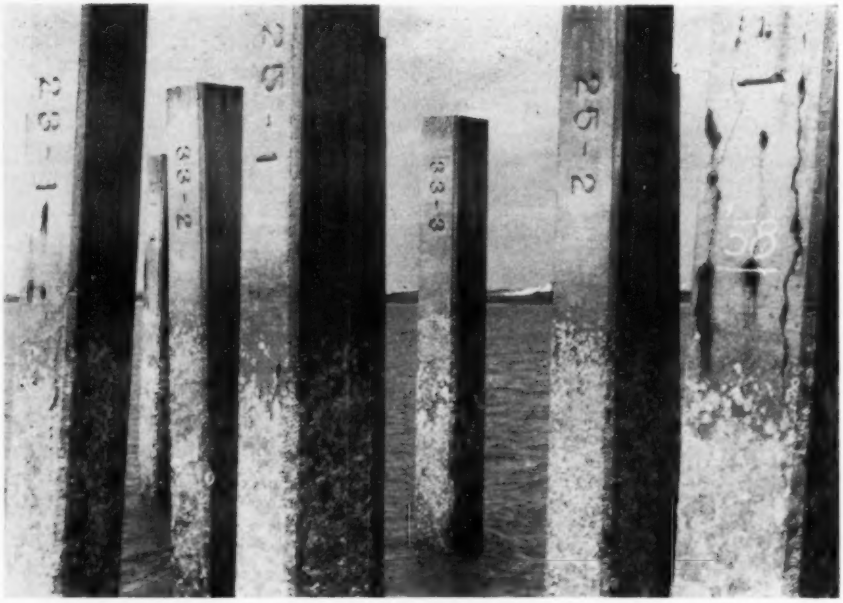


Fig. 3—Cracking and rust staining of test piles at Salt Run, Fla.

Fig. 4—Test piles in Salt Run, Fla., showing sea water attack at corners

are clouded somewhat by cracking as previously noted. Minor surface softening, not considered serious enough to record, has been noted for some time but recently in the case of one cement (Cement 18) this has developed into surface ravelling at corners in all three mixes. Fig. 4 shows the three piles containing Cement 18 at low tide level. Visible deterioration has extended to the depth of the reinforcing steel in some places with the most severe attack at or below mid-tide level. Soniscope tests indicate that deterioration is confined to the 2 or 3 in. of concrete adjacent to corners. The following statements appear to be warranted regarding the piling installation in Salt Run.

1. As at Cape Cod, and to a more limited extent at Saugerties, the cover over reinforcing steel was insufficient to prevent cracking. This is the most obvious manifestation at St. Augustine.

2. The effects of mix proportions on cracking are clearly shown; the 5-sack, 2-in. slump concrete having the most cracking and the 7-sack, 2-in. slump concrete the least.

3. Differences among the cements appear to be significant for the first time. Cement 18, the highest in C_3A, shows severe surface softening and ravelling at corners.

TABLE 4—LINEAL FEET OF CRACKING IN EACH PILE AT SALT RUN, ST. AUGUSTINE, FLA., 1958

Cement No.	Mix 1, 5 sack, 2 in. slump	Mix 2, 7 sack, 2 in. slump	Mix 3, 7 sack, 8 in. slump
11	8	0	3
12	18	0	0
13	4	0	0
14	0	6	4
15	2	0	0
16	14	0	1
18	5(a)	(b)	1(c)
21	2	0	0
22	20	0	0
23	22	0	12
24	23	5	18
25	14	0	0
31	2	0	3
33	0	0	0
41	22	6	0
42	15	0	0
43	14	0	2
43A	3	0	0
51	14	0	10
12T	0	0	0
16T	2	0	0
21T	0	0	0

(a) Severe softening and deterioration above low tide level
(b) Softening and deterioration above low tide level
(c) Softening and deterioration above low tide level

TABLE 5—LINEAL FEET OF CRACKING IN EACH PILE AT CORONA DEL MAR, CALIF., 1957

Cement No.	Mix 1, 5 sack, 2 in. slump	Mix 2, 7 sack, 2 in. slump	Mix 3, 7 sack, 8 in. slump
11	7	0	2
18	13	0	5
23	8	0	8
34	6	0	13
43	12	0	6
43A	2	0	0
51	17	0	2

4. Effects of air entrainment, though not clear-cut, appear to be beneficial in reducing cracking over the reinforcing steel.

Piles at Corona del Mar (Newport Beach), Calif.

This installation was constructed in 1942 in the mild waters of Newport Bay, protected by the breakwaters of the harbor entrance. Seven of the Long-Time Study cements, including five ASTM types, are represented in the three concrete mixes shown in Table 5. Cracking over the reinforcing steel is the only obvious form of deterioration visible on the specimens after 15 years of exposure.

The following facts seems well established from the data:

1. Cover over the reinforcing steel was insufficient to prevent rusting of the reinforcing steel and cracking of the concrete for two of the three mixtures.

2. Cracking was most severe in the 5-sack concrete mixture; entirely absent on the 7-sack, 2-in. slump concrete, and intermediate in the 7-sack, 8-in. slump concrete.

3. Effects of cement composition have not appeared.

CONCLUSIONS

There are several generalizations that may be drawn from the performance of the test piles exposed to sea water and to fresh water, most of which are in accord with present thinking regarding construction for these environments. Test results are somewhat obscured by two facts: first, the excessive cracking in sea water in both mild and severe exposures and, second, the introduction of acid contamination in the case of the fresh water exposure. But in spite of the disturbing influence of these forces which was not contemplated when laying out the test projects, the following conclusions seem valid.

1. In all of the sea water projects and to a lesser extent in the fresh water exposure the 1½ in. of concrete cover was insufficient to prevent rusting of reinforcing steel and cracking of concrete. Visual comparisons indicate the rusting and cracking was more severe in the two mild sea water exposures.

2. Water-cement ratio, as represented by richness of mix and slump of concrete, played an important role in all exposures, including the fresh water series that was complicated by acid exposure. In every case the 7-sack, 2-in. slump specimens (water-cement ratio about 5 gal. per sack) were superior after 15 to 17 years' exposure. The 5-sack, 2-in. slump (7 gal. per sack) specimens showed the poorest performance. Results from the Cape Cod exposure are such as to support Table 4 in the ACI Standard "Recommended Practice for Selecting Proportions for Concrete (ACI 613-54)" in which 4.5 to 5.0 gal. of water per sack of cement is recommended as the maximum water-cement ratio for air-entrained concrete exposed to sea water under severe weathering conditions.

3. Air entrainment was somewhat beneficial to both sea water exposures in which it was used, more so in the case of severe weathering than in the exposure to mild climate.

4. For the fresh water exposure with acid contamination, cement composition was not shown to be of significance.

5. The first positive indication of chemical attack by sea water has appeared at the St. Augustine installation in the case of one cement

only. Here the cement of highest potential C_3A content (Cement 18) showed attack in all three concrete mixtures. This cement has been shown in other test projects to be the most susceptible of all the Long-Time Study cements to sulfate attack. While the attack is most severe on the lean specimens, the rich stiff mix is also attacked sufficiently to show that use of a rich mix in itself is insufficient to afford complete protection. It would appear from this and the findings of other investigators that sea water attack is similar to that of strong sulfate solutions except that the action is much slower.

6. Absorptive form liners used with the lean mix in the severe exposures have not had a significant effect on performance of concrete.

This investigation seems unlikely to develop information sufficiently detailed to permit recommendations for cements exposed to sea water even though one of the cements shows definite signs of deterioration and offers a strong indication that C_3A content should be of prime consideration, particularly in the high ranges. This is corroborated by data from the sea water exposure construction by the Corps of Engineers adjacent to Project 8C at St. Augustine.

In view of the results which seem inevitable from the present course of developments on the Long-Time Study investigation, the Long-Time Study Advisory Committee, consisting mainly of prominent engineers representing consumers of cement, has recommended that an additional sea water exposure including a more comprehensive list of cements be undertaken immediately to investigate more thoroughly the matter of resistance of concrete to sea water. To this end, some eight hundred 6 x 6 x 30-in. test specimens representing 50 cements or cement-admixture combinations have been fabricated and are now under exposure at San Pedro, Calif. A long time must elapse before conclusive developments from the new installation will be useful to builders of marine structures and the present paper may therefore be a useful guide until data from the new investigation or contributions from other investigators supply the much needed information.

REFERENCES

1. Stanton, Thomas E., and Meder, Lester C., "Resistance of Cement to Attack by Sea Water and by Alkali Soils," ACI JOURNAL, V. 9, No. 4, Mar.-Apr. 1938 (*Proceedings* V. 34), pp. 433-464.

2. Hadley, Homer M., "Concrete in Sea Water; A Revised View Point Needed," *Transactions*, ASCE, V. 107, 1942.

3. Stanton, Thomas E., "Durability of Concrete Exposed to Sea Water and Alkali Soils—California Experience," ACI JOURNAL, V. 19, No. 9, May 1948 (*Proceedings* V. 44), pp. 821-847. Discussions in ACI JOURNAL, V. 20, No. 4, Part 2, Dec. 1958 (*Proceedings* V. 44), pp. 848-1—848-18.

4. Cook, Herbert K., "Experimental Exposure of Concrete to Natural Weathering in Marine Locations," *Proceedings*, ASTM, V. 52, 1952.

5. "Factors Affecting Durability of Concrete in Coastal Structures," *Technical Memorandum* No. 96, Beach Erosion Board, Office, Chief of Engineers, Department of the Army, June 1957.

6. Wakeman, C. M.; Dockweiler, E. V.; Stover, H. E.; and Whiteneck, L. L., "Use of Concrete in Marine Environments," ACI JOURNAL, V. 29, No. 10, Apr. 1958 (*Proceedings* V. 54), pp. 841-856.

Received by the Institute Nov. 23, 1959. Title No. 56-45 is a part of copyrighted Journal of the American Concrete Institute, V. 31, No. 9, Mar. 1960 (Proceedings V. 56). Separate prints are available at 50 cents each.

American Concrete Institute, P. O. Box 4754, Redford Station, Detroit 19, Mich.

Discussion of this paper should reach ACI headquarters in triplicate by June 1, 1960, for publication in the Part 2, September 1960 JOURNAL.

Title No. 56-46

Yield Moments of Reinforced Concrete Beams and Columns

By CLARENCE W. DUNHAM and HANS GESUND

A numerical method is developed for finding the moment at which the tensile reinforcement in a reinforced concrete beam will just reach the yield point if the beam is under-reinforced, or at which the concrete will reach its ultimate strain if the beam is over-reinforced. Curves are drawn of M/bd^2 versus p for a variety of assumed concrete stress-strain curves. The method is also applied to eccentrically loaded columns, and curves of yield load versus eccentricity (both in dimensionless form) are drawn for square, rectangular, and circular columns with a variety of percentages of reinforcement and various assumed concrete stress-strain curves. The extension of this method to columns with bending in two directions is outlined.

■ THE PURPOSE OF THE STUDIES, the results of which are reported here, was to develop a general method of computing the yield strength of reinforced concrete members subjected to bending with or without accompanying axial compression. The proposed method of analysis is to utilize the stress-strain diagram for the concrete and the corresponding stress-strain relationship of the reinforcement, assuming no major bond failure along the bars. By use of one standard method of procedure it is then possible to compute the ultimate strength of members composed of any quality of concrete, grade of steel, shape of cross section, arrangement of reinforcement, and combination of axial loads and moments.

BEAMS

Present methods of, and formulas for, ultimate load design* are based on the assumption and requirement that the tensile reinforcement shall yield before compression failure occurs in the concrete. At the same time, however, the stress block which is assumed to exist in the concrete is that for which the outermost compression fibers are at their ultimate strain. This, obviously, can occur only after the steel has under-

*Appendix of "Building Code Requirements for Reinforced Concrete (ACI 318-56)," American Concrete Institute.

ACI member **Clarence W. Dunham** is associate professor of civil engineering at Yale University and a consulting structural engineer, Anaconda-Jurden Associates, Inc., New York. He was formerly a structural designer with the Port of New York Authority and has written numerous books and papers on the design of reinforced concrete structures. • **Hans Gesund**, ACI member, is associate professor of structural engineering at the University of Kentucky and was formerly an instructor of civil engineering at Yale University.

gone extensive local yielding, with large cracks opening in the concrete and great deflection of the beam, unless there is a large percentage of tensile steel. For beams of normal proportions, it is virtually impossible to put enough reinforcement into the beam to strain the concrete to its ultimate value, or even to its maximum stress, without having the steel yield. All this has been pointed out numerous times in the literature, and many attempts have been made to find the yield moment of under-reinforced beams. All of them have assumed that some mathematical function describes all stress-strain curves. It is, however, not possible to state at present what type of compression test should be used to obtain the stress-strain data. It is hoped that this question may be answered in the future by using the method to be described for finding the yield moment and to correlate compression and flexure test results. In this method, any compressive stress-strain curve for the concrete may be used to obtain the compressive stress block when the steel yields, and from this, the location of the centroid of compression. Knowing the latter, the bending moment causing the steel to yield is easily found.

Notation

A_s = area of tension reinforcement
A_s' = area of compression reinforcement
b = width of beam or column
d = depth of beam to center of gravity of tensile reinforcement
D = depth of column (over-all)
e = eccentricity of axial compressive load P from the geometric center of the cross section
ε_c = strain in the outermost compression fiber of the concrete
ε_s = strain in the tensile reinforcement
ε_y = yield strain of steel
E_s = modulus of elasticity of steel
f_s = stress in the tensile reinforcement
f_s' = stress in the compressive reinforcement
f_y = yield stress of steel
f_c = stress in the outermost compression fiber of the concrete
f_c' = greatest stress the concrete can withstand in standard cylinder test
jd = distance from the centroid of compression to the centroid of tension
kd = distance from compression face of a beam to the neutral axis
k_1f_c = average stress in the concrete of a beam, so that k_1f_cbd equals the total compressive force in the concrete
k_2d = distance from the compression face of a beam to the centroid of compression
m = distance from compression edge of a column to the line of action of the axial load

M = bending moment, applied or resisting

M_μ = ultimate strength of a beam in bending

$p = \frac{A_s}{bd}$ for a beam

$p' = \frac{A_s'}{bd}$

$p_g = \frac{A_s + A_s'}{bD}$ for a column

P = load on a column

P_{os} = maximum axial load which a short column can support

P_μ = yield load which a column can support at a given eccentricity

THEORY

As long as a beam is under-reinforced, the shape and magnitude of the compressive stress block when the tensile reinforcement yields will be directly related to the total tensile force and the stress-strain curve of the concrete in compression. For any given characteristics of concrete and steel, the stress block will then depend on the percentage of reinforcement, p. In Fig. 1, a beam is shown with several different strain distributions and their assumed respective compressive stress blocks. A successively larger p is assumed in Fig. 1 (b), (c), and (d), and the stress block is based on the concrete compressive stress-strain diagram A of Fig. 3.

If the average stress in the concrete is expressed as $k_1 f_c$, then total tensile force in the steel at the yield point must equal total compressive force in the concrete, or

$$k_1 f_c bkd = A_s f_y$$

or

$$k_1 f_c k = p f_y \qquad (1)$$

Now, assuming some ε_c (preferably a small one at first), it is possible to find p. First, to find k, it may be observed that if plane sections remain plane in bending, geometry gives

$$\frac{kd}{d - kd} = \frac{\varepsilon_c}{\varepsilon_y}$$

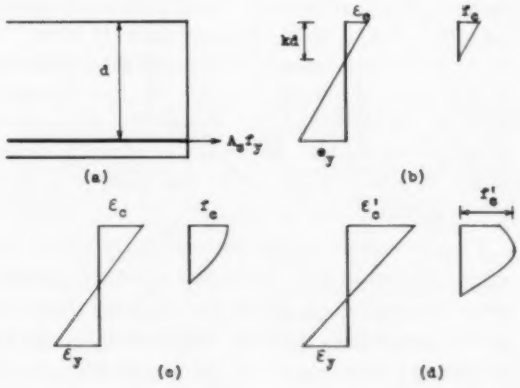
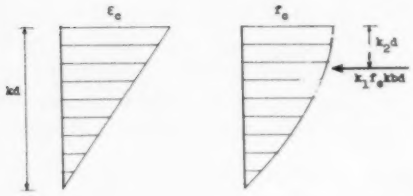


Fig. 1 — Various strain and stress distributions in reinforced concrete beams

Fig. 2 — Strain and stress diagrams divided into strips



from which

$$k = \frac{\varepsilon_c}{\varepsilon_c + \varepsilon_y} \qquad (2)$$

Fig. 2 shows a strain diagram and the corresponding stress distribution for some assumed ε_c. Note that, for correspondence with Eq. (1), d is taken equal to unity, as is also b, although, of course, b need not equal d.

It is possible to divide the strain triangle into any convenient number of strips. Knowing the strain at each dividing line, the stress block may be drawn and similarly divided into strips by referring to the stress-strain diagram (Fig. 3) and plotting the unit stress which accompanies each particular strain. The sum of the volumes of all the strips in the stress block gives $k_1 f_c k$ needed to counterbalance the tensile force in the steel. Then the required p may be found from Eq. (1), since f_y is a known quantity.

Next, finding the sum of the static moments of the strips of the stress block about the top, and dividing that sum by the total volume of the stress block, k_2 may be found. Then $1 - k_2 = j$ gives the lever arm of the tensile reinforcement for the unit depth. Multiplying $k_1 f_c k$ by j gives M/bd^2.

The above procedure may be repeated with several different values of ε_c, and a graph of M/bd^2 versus p may be constructed. This graph will apply to all beams made with that particular mix of concrete, grade of steel, shape, and arrangement of bars. For any given beam then, if p, b, and d are known, the yield moment may be found. Conversely, for any choice of p and a known M, the necessary cross section of the beam may be determined. It should be noticed that this is not the ultimate moment at which the beam is already cracked wide open, but the moment at which yielding of the steel will first take place, which is really the ultimate usable strength of the member.

The presence of compressive reinforcement may be taken into account by finding f_s' from the strain diagram and E_s (note the maximum possible value of f_s' is f_y) and adding $f_s'p'$ as an additional area to the appropriate strip in the stress block, less the area of concrete displaced by the bars. As an alternate, the force in the compressive re-

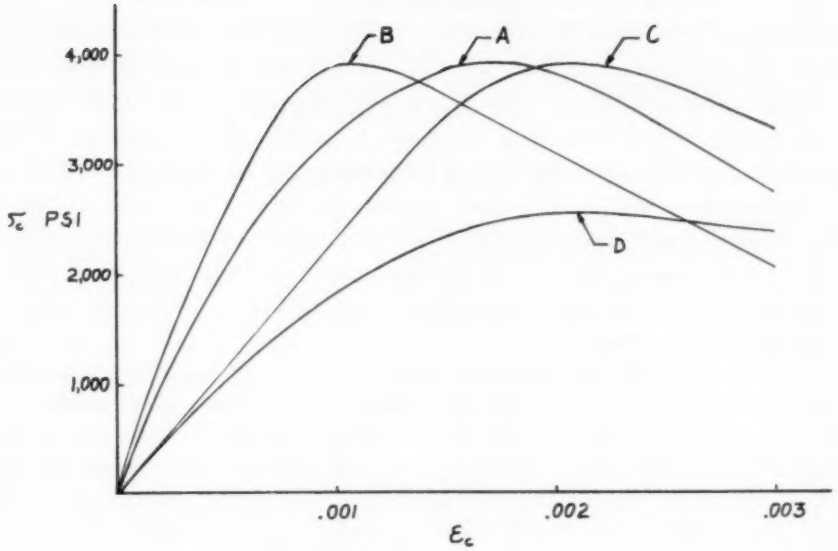


Fig. 3 — Concrete stress-strain curves

inforcement minus the force in the concrete removed by the bars may be multiplied by the lever arm between the compressive reinforcement and the centroid of the tensile steel, then this moment may be added to that of the concrete alone in compression. T-beams and other nonrectangular members may be handled similarly, by increasing or decreasing the area of the proper strips of the stress block by an appropriate amount to reflect the change in width. The p for T-beams must be based on the width of the stem.

DISCUSSION

Fig. 4 represents the M/bd^2 versus p curves for rectangular beams using concrete stress-strain curves A, B, and C of Fig. 3. It is interesting to note how little effect the *shape* of the concrete stress-strain curve has. It is also interesting that all the curves of M/bd^2 versus p are almost straight lines until extremely large values of p are reached. If the portions of the concrete stress-strain curves beyond f_c' were not used, the M/bd^2 curves would end at the points marked "Curve—concrete reaches f_c'." The steel used was assumed to have a yield point of 40,000 psi and a modulus of elasticity of 30,000,000 psi. For comparison, M/bd^2 was also plotted as point X in Fig. 4 against its p, using balanced

elastic design with an allowable steel stress of 20,000 psi and an allowable concrete stress of $0.45f_c'$.

A comparison of the proposed method with ultimate strength design according to the ACI Building Code (ACI 318-56) was also made. Using a maximum allowable $p = 0.4\ f_c'/f_y = 0.04$ the ultimate moment becomes $M/bd^2 = 1220$ psi. This is precisely the value of M/bd^2 for which the concrete of Curve A is stressed to its maximum possible stress, though it will happen with a p of 0.039 according to the method of analysis here described. Using other values of p in the ACI Code formulas for ultimate load design produces similarly close agreement. Since the ACI Code is based on having the beam cracked wide open, this would indicate that, once the steel yields, there is very little more reserve strength in the beam.

For any normal or irregular shapes and arrangements of bars, the method presented herein can be used by drawing the cross section to scale, using the areas of strips times the appropriate ordinates from the stress-strain curve for a given or assumed neutral axis, computing the total value of the compressive resistance, and locating the center of gravity of the compressive block with respect to that of the tensile steel.

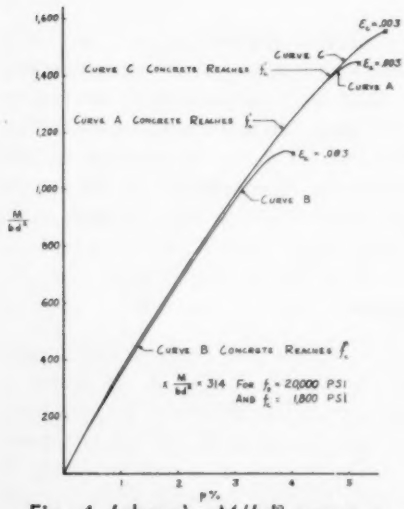


Fig. 4 (above)—M/bd^2 versus p

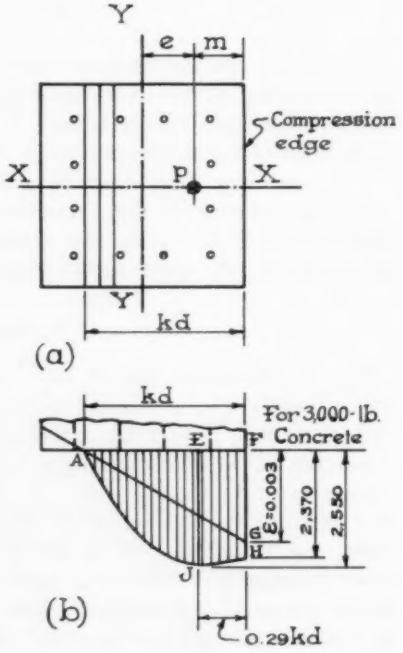


Fig. 5 (right)—(a) Short, tied column. (b) Stress-strain diagram for concrete equal to Curve D of Fig. 3

Then $M_\mu = A_s f_y$ times the lever arm between the centers of gravity of the resultant tensile and compressive forces.

The proposed method of analysis can be used in the case of over-reinforced beams if, for some reason, such members are necessary. The stresses in both steel and concrete can then be determined from the assumed strains, and the total forces of tension and compression may be computed, as can the lever arm between their centroids.

COMBINED BENDING AND AXIAL COMPRESSION

Since the proposed method of analysis can also be used when the steel is not stressed to its yield point, for any selected straight line strain distribution, for any irregular shape, for any arrangement of bars, and for any stress-strain diagram representing the compressive properties of the concrete, the authors believe that this method can be employed to advantage in the analysis of members having combined bending and compression. It is readily adjustable to any specifications which may be set up to limit the maximum compressive strain, the yield stress in the steel, and the stress-strain diagram for the concrete. This is important because, as new materials are developed and as further experience is gained, the suggested method of analysis can be adapted to whatever limitations may be necessary, even to the extent of using a nonlinear variation of strains across the section.

The method of analysis will be illustrated by direct application to a problem.

Assume the short, tied column of Fig. 5(a). Compute the ultimate compressive load P_μ if the eccentricity e about the axis Y-Y equals 4 in. Use the data given in Fig. 5(b), where AFHJ represents the assumed stress-strain diagram for the concrete equal to Curve D of Fig. 3. Let f_y equal 40,000 psi. Assume the maximum allowable strain in the concrete to be 0.003, as shown by FGA in Fig. 5(b); the maximum tensile strain in the steel is to be approximately 0.00133, corresponding to $f_y =$ 40,000 psi.

The stress-strain diagram in Fig. 5(b) is patterned after Hognestad's recommendations* but the maximum strain is limited to 0.003.†

It is possible to select an assumed neutral axis parallel to Y-Y, divide kd into strips parallel to Y-Y, compute the forces in the strips of concrete and in the steel, determine their moments about the compression edge, and check the value of m and e against their actual values, then to revise the assumed kd and the calculations until e checks the required value of 4 in. When the correct kd is determined, P_μ equals the algebraic sum of the forces in the concrete and the steel.

---

*Hognestad, Eivind, "A Study of Combined Bending and Axial Load in Reinforced Concrete Members," *Bulletin* No. 399, University of Illinois Engineering Experiment Station.

†The maximum ordinate EJ is 0.85 f'_c.

For example, assume that kd for the case selected for this problem is 12 in. and that the failure will be due to crushing of the concrete before the steel yields. Draw the cross section of the column as shown in Fig. 6(a), locate the assumed neutral axis, draw the stress block for kd = 12 in. and $\varepsilon = 0.003$, to large scale, as shown in Fig. 6(b). Divide the compression zone into some reasonable number of strips, depending upon the degree of accuracy desired. In this case, 12 strips will be used as shown in Fig. 6(a). Then scale the ordinates in Fig. 6(b) corresponding to the locations of the centers of these strips. The computations for the concrete are given in Table 1, where ΣF_c is the total compressive force and ΣM_c is the moment of the slices of the stress block about the compression edge.

As a check of the computations, calculate the force ΣF_c and the moment ΣM_c as shown in Table 2. The results agree with those of Table 1

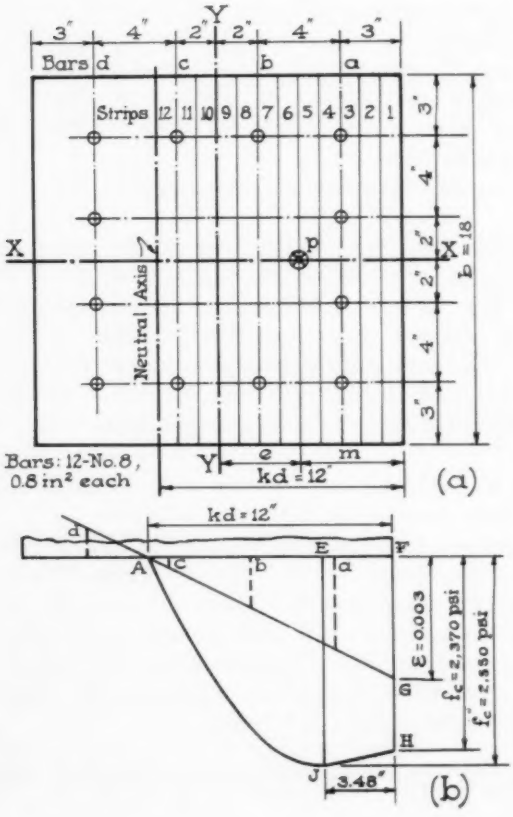


Fig. 6 — (a) Cross section of column in Fig. 5 (a) with an assumed neutral axis and an arbitrary number of stress strips. (b) Stress block for kd = 12 in. and $\varepsilon = 0.003$

as well as can be expected when values for the latter are scaled from the drawings.

To compute the effect of the "holes" in the concrete caused by the bars, perform the calculations shown in Table 3. Then deduct these

TABLE 1—EXAMPLE CALCULATION OF ΣF_c AND ΣM_c FOR A SQUARE REINFORCED COLUMN*

For kd = 12 in. for concrete

Strip No.	Area, sq in.	f_c, ksi	ΔF_c, kips	Lever arm, in.	ΔM_c, in.-kips
1	18	2.41	43.4	0.5	22
2	18	2.47	44.5	1.5	67
3	18	2.53	45.5	2.5	124
4	18	2.55	45.9	3.5	161
5	18	2.52	45.4	4.5	204
6	18	2.40	43.2	5.5	237
7	18	2.24	40.3	6.5	262
8	18	1.99	35.8	7.5	268
9	18	1.67	30.1	8.5	256
10	18	1.27	22.9	9.5	218
11	18	0.83	14.9	10.5	156
12	18	0.31	5.6	11.5	64
Σ			ΣF_c = 417.5 kips		ΣM_c = 2039 in.-kips

*See Fig. 6(a) and (b).

TABLE 2—COMPUTATIONS FOR STRESS BLOCK 1 IN. WIDE

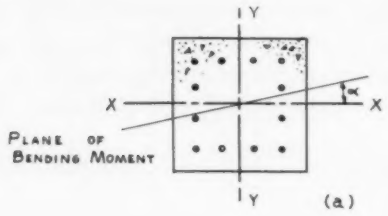
Part	Area, sq in.	ΔF_c, kips	Lever arm, in.	ΔM_c, in.-kips
Rectangle	2.37 × 3.48	= 8.25	1.74	14.35
Triangle	0.18 × $\frac{3.48}{2}$	= 0.31	2.32	0.72
Parabola	2/3 × 2.55 × 8.52	= 14.50	(3/8 × 8.52) + 3.48	= 6.68 96.90
		ΣF_c = 23.06 kips × 18		ΣM_c = 111.97 in.-kips × 18
		Total F_c = 415 kips		Total M_c = 2015 in.-kips

TABLE 3—DEDUCTIONS FOR HOLES IN CONCRETE

Bar No.	Area, sq in.	f_c, ksi	ΔF_c, kips	Lever arm, in.	ΔM_c, in.-kips
a	3.2	2.55	8.16	3	24.5
b	1.6	2.13	3.41	7	23.9
c	1.6	0.58	0.93	11	10.2
d	—				
			ΣF_c = 12.50 kips		ΣM_c = 58.6 in.-kips

TABLE 4—REINFORCEMENT

Bar No.	Area, sq in.	Strain, in. per in.	F_s, ksi	ΔF_s, kips	Lever arm, in.	ΔM_s, in.-kips
a	3.2	0.00225	40	128	3	384
b	1.6	0.00125	37.5	60	7	420
c	1.6	0.00025	7.5	12	11	132
d	3.2	−0.00075	−22.5	−72	15	−1080
				ΣF_s = 128 kips		ΣM_s = −144 in.-kips



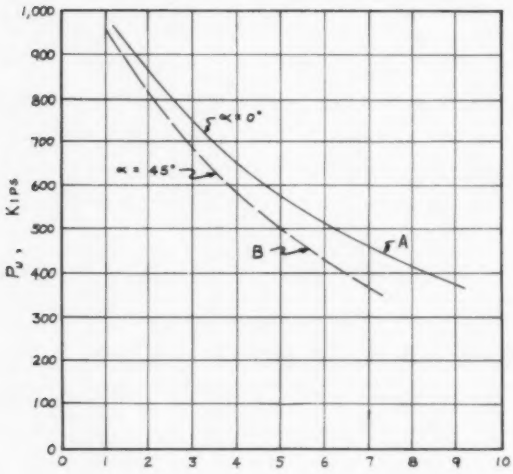


Fig. 7 — (a) Plane of bending moment. (b) A plot of yield load P_μ against the eccentricity e for an axial compressive load

values from those of Table 1 to find the following: *

$$\text{Net } \Sigma F_c = 417.5 - 12.5 = 405 \text{ kips}$$
$$\text{Net } \Sigma M_c = 2039 - 59 = 1980 \text{ in.-kips}$$

Now, to determine the effect of the steel, draw the strain diagram FGA in Fig. 6(b), project from Fig. 6(a) to 6(b) to find the strains in each set of bars, or compute them directly, then complete the calculations shown in Table 4, remembering that the maximum steel stress is 40,000 psi.

The total forces and moments on the net section are therefore

$$P_\mu = 405 + 128 = 533 \text{ kips}$$
$$M_c = 1980 - 144 = 1836 \text{ in.-kips}$$

Therefore,

$$m = M_c/P_\mu = 1836/533 = 3.45 \text{ in. and } e = 9 - 3.45 = 5.55 \text{ in.}$$

It is obvious that e does not agree with the 4 in. specified.

Instead of changing kd and revising the computations, it is more desirable to assume various values of kd and to plot a curve of $P\mu$ versus e

*Generally it is sufficient to assume that the gross values of ΣF_c and ΣM_c can be multiplied by $1-p_g$ to find the net values.

for the member. In this case, kd was assumed to be 18, 16, 14, 12, and 10 in. In the last of these cases, ε_s would be 0.0015, a little over the 0.00133 limit set. Since the steel strain is not to be permitted to exceed the yield strain, the maximum concrete strain must be reduced for this and all lesser values of kd. Curve A shown in Fig. 7 can then be plotted. For $e = 4$ in., Curve A gives $P_\mu = 645$ kips (approximate). This curve can be used for many combinations of axial load and bending for this particular member.

Various short cuts can be devised for facilitating the computations. For example, by drawing the assumed strain diagram so that the maximum tensile strain in the steel is 0.00133 and the maximum compressive strain in the concrete is 0.003, or as desired, the neutral axis can be located for the smallest acceptable kd. Then the stress block for this condition can be drawn as shown by AFHJ in Fig. 8. For any larger kd, draw AV from A to line FV, making its length equal to the new value of kd, and locate the centers of the strips along AV as shown by the dots. Also locate the bars as shown by the cross lines. By projecting parallel to FV to the stress block the values of the ordinates can be scaled directly, giving the same quantities as though the stress block were redrawn on a new base equal to the longer kd.

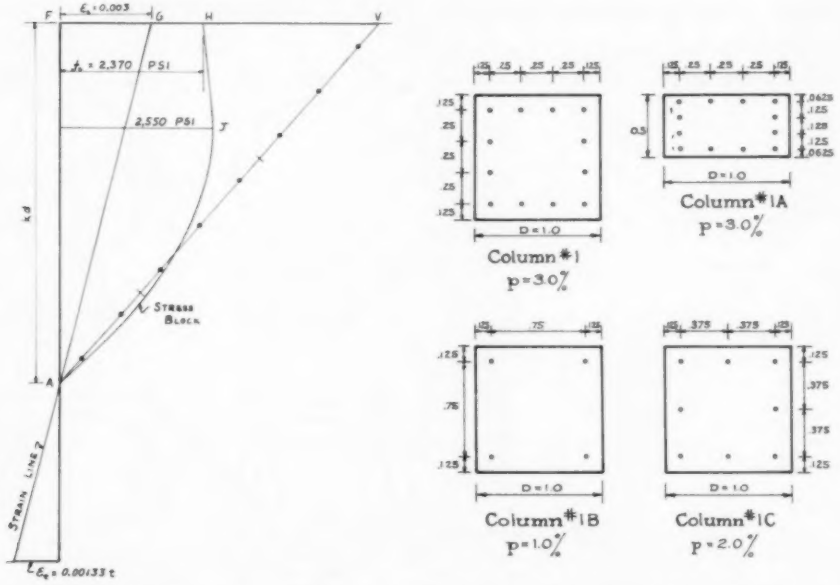


Fig. 8 (left)—Stress block used to facilitate computation of values that are employed in plotting curves like those in Fig. 7(b). Fig. 9 (right)—Column cross sections

It is possible to carry out the calculations described above in such a manner as to obtain dimensionless results. This has been done, utilizing Curves A, B, C, and D of Fig. 3 and the assumed column cross sections of Fig. 9 to 11, inclusive. In each case, the dimensions are shown as fractions of an assumed unit depth D in the direction of bending, and the total percentage of steel area to gross area p_g is distributed within the columns as shown. The results are expressed in curves of yield load divided by possible axial load plotted against e/D, as shown in Fig. 12 to 15, inclusive. Fig. 12 shows the effect of variation in cross section for rectangular columns, and Fig. 13 shows the same thing for circular columns. The same concrete stress-strain diagram, Curve A of Fig. 3, was used throughout. Fig. 14 and 15 show the effects of the various stress-strain curves, utilizing two different column cross sections, Number 1, square, and Number 3, circular. It is again interesting to note how small the effects of changes in the concrete stress-strain curve and in the percentage of reinforcement are.

SKEW BENDING

The method may also be applied in the case of 45 deg skew bending of square, symmetrically reinforced columns. The strips must be drawn perpendicular to the plane of bending and all moments should be taken about a line perpendicular to the plane of bending through the com-

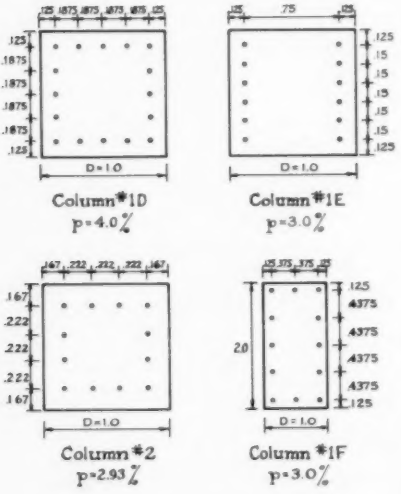


Fig. 10 (above)—Column cross sections

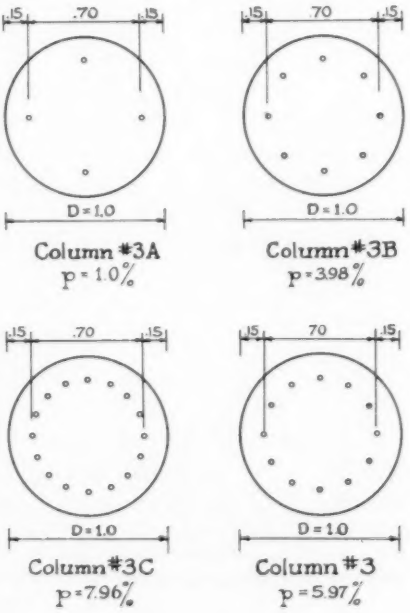


Fig. 11 (right)—Column cross sections

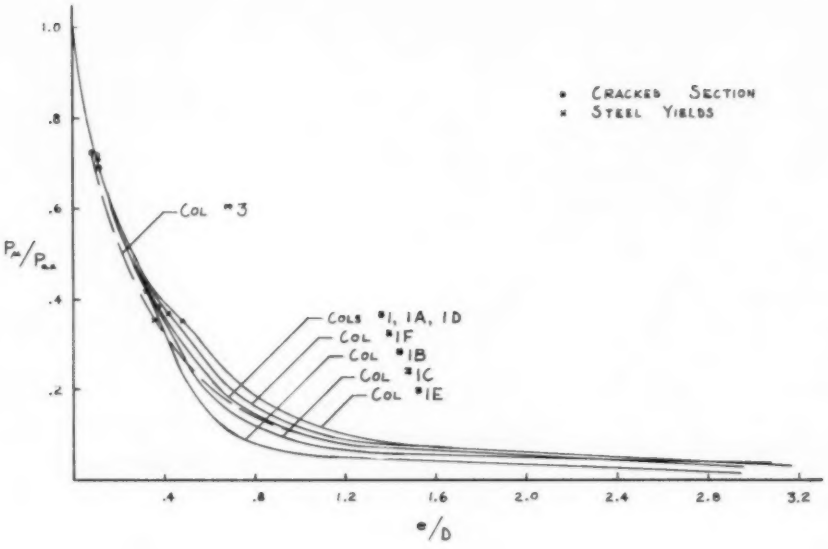


Fig. 12—Effect of various cross sections—Curve A

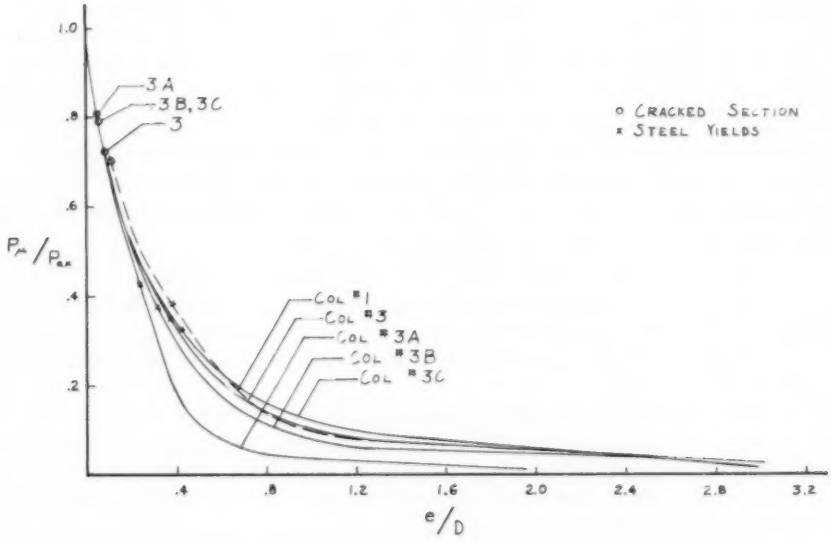


Fig. 13 — Effect of various cross sections — Curve A

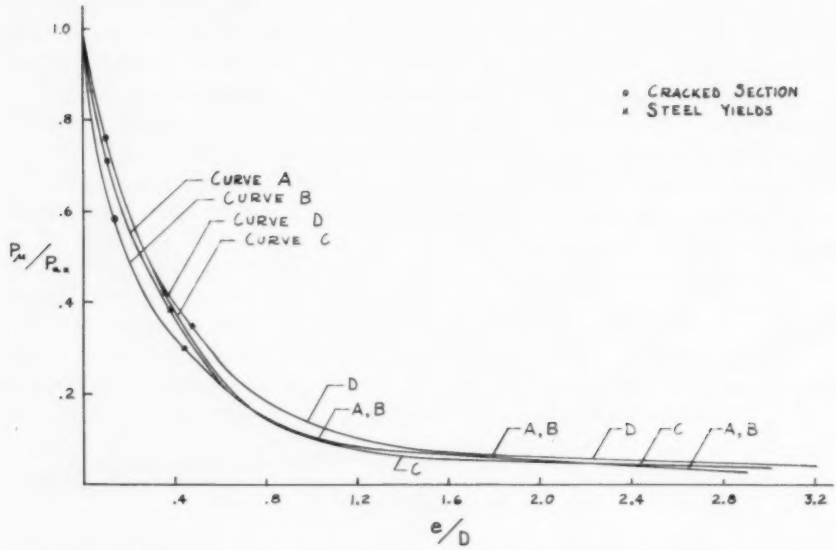


Fig. 14—Effect of various concrete stress-strain curves—Column No. 1

pression corner rather than about the compression edge. For the 18-in. square column of Fig. 5(a) the curve of P_μ versus e for the 45 deg skew case is shown as Curve B of Fig. 7(b).

Skew bending of rectangular columns, and of square columns at angles other than 45 deg may be handled by some modification of the method used heretofore. The principle used is that the sum of the moments about any axis must be equal to zero. Thus a neutral axis may be chosen at any angle, and moments of the forces in the steel and in the concrete strips taken about the neutral axis and about a line perpendicular to it. Having the total moment in each direction as well as the total vertical force, P_μ as well as its exact location may be found. The steps involved may be outlined as follows:

1. Draw any desired neutral axis and a line perpendicular to it.
2. Draw the strain diagram to agree, assuming linear strain variation with distance from the neutral axis.
3. Divide the column cross section into strips parallel to the assumed neutral axis.
4. Find the force in each strip using the stress-strain curve of the concrete.
5. Find the moment of the force in each strip both about the neutral axis and the line perpendicular to it.
6. Find the force in each bar, subtracting that of the concrete it replaces in case of compression steel.
7. Find the moments of the steel about the neutral axis and the line perpendicular to it.

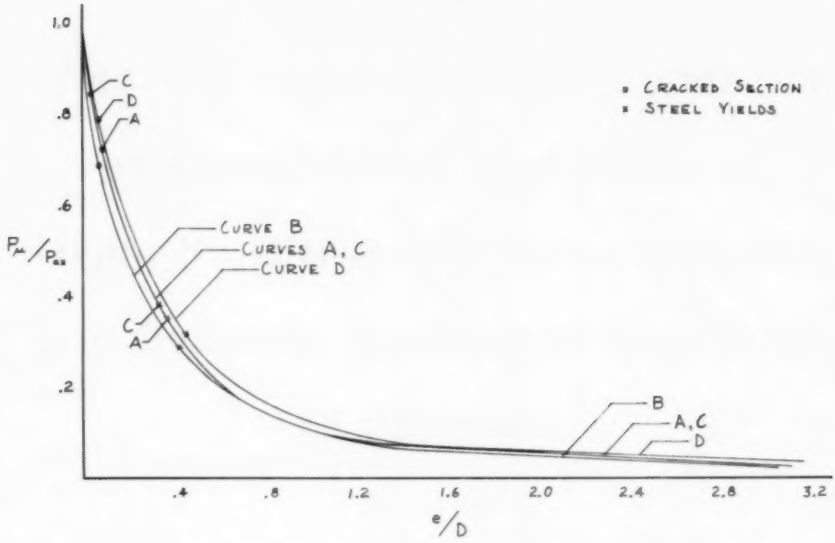


Fig. 15 — Effect of various concrete stress-strain curves — Column No. 3

8. Find the sum of the forces and moments about both axes, and calculate the magnitude and location of the load.

9. Find the moments M_x and M_y about any convenient set of axes in the column.

10. Plot P_μ/P_{ezero} against e_x/D and e_y/D for a variety of inclinations of the neutral axis.

11. If the same number of strips is always used, then for any one $\varepsilon_{c\,max}$ several angles of the neutral axis can be done at one time using the same stress each time in the corresponding strip. This will save some time.

After a sufficient number of points have been plotted, it will be possible to draw curves similar to those of Fig. 12 through Fig. 15 for various directions of the plane of bending.

ACKNOWLEDGMENT

The data for the curves was computed on the IBM 650 of the University of Kentucky, and the authors would like to express their gratitude to the university and the Kentucky Research Foundation for making the machine available.

Received by the Institute June 1, 1959. Title No. 56-46 is a part of copyrighted Journal of the American Concrete Institute, V. 31, No. 9, Mar. 1960 (Proceedings V. 56). Separate prints are available at 60 cents.

American Concrete Institute, P. O. Box 4754, Redford Station, Detroit 19, Mich.

Discussion of this paper should reach ACI headquarters in triplicate by June 1, 1960, for publication in the Part 2, September 1960 JOURNAL.

Effects of Incomplete Consolidation on Compressive and Flexural Strength, Ultrasonic Pulse Velocity, and Dynamic Modulus of Elasticity of Concrete

By M. F. KAPLAN

An experimental investigation has been conducted to determine the effects of voids due to incomplete consolidation on the compressive and flexural strength, ultrasonic pulse velocity, and dynamic modulus of elasticity of concrete.

Concrete mixes having cement:aggregate:water ratios of 1:3:0.35, 1:6:0.50, and 1:9:0.66, by weight, were used to make 20 x 4 x 4-in. beams and 6-in. cubes for resonant frequency and flexural and compressive strength tests. The tests were done after 7, 28, and 91 days. Pulse velocity measurements were also made on all specimens before carrying out the other tests. The amount of consolidation was varied by vibrating the concrete for different lengths of time. The maximum void content was 32 percent.

The effects of incomplete consolidation on compressive and flexural strength, pulse velocity, and dynamic *E* are reported and the interrelationships between these properties examined.

■ INCOMPLETE CONSOLIDATION OF CONCRETE in construction work is a not uncommon occurrence. Although data exist regarding the effects of air voids on compressive strength due to incomplete consolidation, little information is available concerning its effect on flexural strength, ultrasonic pulse velocity, and the modulus of elasticity of concrete.

Experiments have been conducted to obtain further information on the above properties and to investigate the relationships between pulse velocity and strength, and between dynamic modulus of elasticity and strength, for concrete containing air voids due to incomplete consolidation.

EXPERIMENTAL DETAILS

Concrete mixes were prepared having cement: aggregate: water ratios of 1:3: 0.35, 1:6:0.50, and 1:9:0.66, by weight. The workability of these mixes was the same with the nominal compaction factor[1] being 0.80; this corresponded to a slump of approximately 1 in. The fine aggregate was a siliceous river sand and the coarse aggregate was crushed norite having a maximum size of 3/4 in. Aggregates were dried before being used and the grading was the same for all

M. F. Kaplan heads the Civil Engineering Division of the National Building Research Institute, South African Council for Scientific and Industrial Research, Pretoria. Dr. Kaplan was awarded a CSIR research bursary for overseas study in 1953 at the Road Research Laboratory in England and is presently on leave as a research associate at the National Bureau of Standards, Washington, D. C.

mixes; the sand fraction was 42 percent of the total aggregate by weight. Ordinary portland cement taken from a single batch as manufactured was thoroughly mixed and used for all concrete specimens.

The materials were batched by weight and mixed in a pan-type mixer, in accordance with the requirements of BS 1881.[1] Plain concrete beams, 20 x 4 x 4 in., and 6-in. cubes were made. The test specimens were fully consolidated in 2-in. layers on a vibrating table, great care being taken to expel as much air as possible. Three batches of fully consolidated beam and cube specimens were made on different days from each concrete mix. Each batch consisted of three beam and three cube test specimens; one beam and one cube specimen from each batch were tested at 7, 28, and 91 days. The incompletely consolidated specimens were also made in batches of three, one specimen being tested at each of the above ages. The amount of consolidation was varied by altering the time of vibration; the least amount of consolidation was obtained when the concrete was simply placed in the mold and the top surface leveled off without any vibration having taken place. The specimens were cured at 21 C (±1 C) and 100 percent relative humidity until required for test. All specimens were weighed

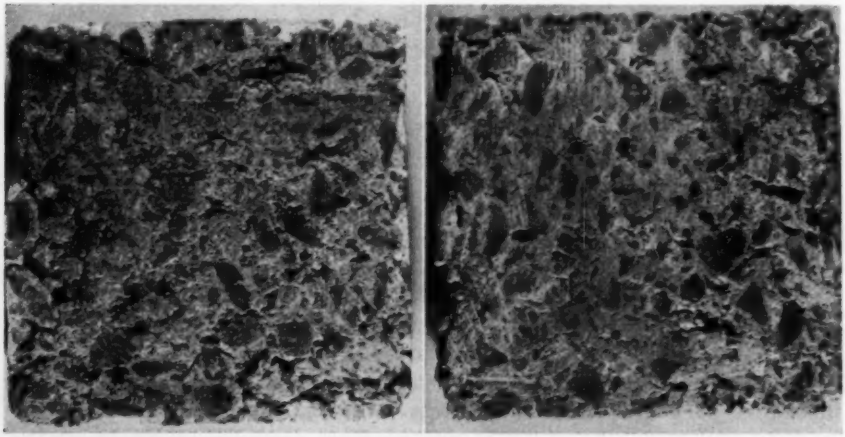


Fig. 1—Sections through 6-in. cubes of incompletely consolidated concrete. (Left) Mix proportions 1:3:0.35; voids = 19 percent. (Right) Mix proportions 1:6:0.50; voids = 22 percent

TABLE 1—PROPERTIES OF FULLY CONSOLIDATED CONCRETE MIXES

	Mix proportions (by weight)								
	1:3:0.35			1:6:0.50			1:9:0.66		
	7 days	28 days	91 days	7 days	28 days	91 days	7 days	28 days	91 days
Compressive strength, psi	7220	8710	10820	4620	6590	7610	2960	4310	5860
Flexural strength, psi	850	990	1060	700	850	890	490	680	740
Pulse velocity, ft per sec	17100	17800	18460	16670	17500	18040	16460	17010	17960
Dynamic $E \times 10^{-6}$ psi	7.2	7.9	8.4	7.3	8.3	8.5	6.7	7.4	7.9
Bulk density, lb per cu ft	158.2			160.6			161.1		

before testing and their bulk density calculated by dividing the weight by the capacity of the mold.

The dynamic modulus of elasticity of the beam specimens was derived from measurements of the natural frequency of the fundamental mode of longitudinal vibration.[1] Ultrasonic pulse velocity through the 4 in. width of the beam specimens and the 6-in. concrete cubes was ascertained;[2] the result for each beam and cube was the average of five and ten measurements, respectively. The flexural and compressive strengths of the beams and the compressive strengths of the cubes were determined in accordance with Parts 11, 9, and 8, respectively, of BS 1881.[1]

Average results for the fully consolidated test specimens are given in Table 1.

BULK DENSITY AND VOID CONTENT

The average experimental bulk density of the fully consolidated specimens did not differ significantly from that calculated theoretically. This indicated that there was very little air entrapped in the concrete. The average experimental bulk densities were 158.2, 160.6, and 161.1 lb per cu ft for the 1:3, 1:6, and 1:9 mixes, respectively. These comparatively high densities were primarily due to the norite coarse aggregate which had a specific gravity of 3.01.

The bulk densities of incompletely consolidated test specimens of the same mix proportions varied, even though they were vibrated for the same length of time. As shown in Fig. 1, the air voids were not uniformly distributed, were irregular in shape, varied in size, and were often interconnected. The void content was obtained by expressing the difference in the fully and incompletely consolidated weights as a percentage of the fully consolidated weight. The highest percentage voids, *viz.* 32 percent, occurred in the leanest (1:9) mix when no effort was made to compact the concrete.

COMPRESSIVE STRENGTH

As mentioned above, incompletely consolidated test specimens, although vibrated for the same period, varied in density. To obtain average values,

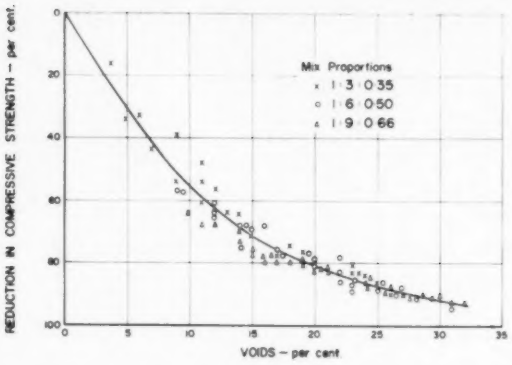


Fig. 2 — Percentage reduction in compressive strength due to incomplete consolidation

specimens were grouped in density class intervals of approximately 2.5 lb per cu ft. The average compressive strength of the specimens falling within a group was taken to be the strength of the concrete corresponding to the average density of the specimens within the group.

The number of incompletely consolidated specimens within a group was generally three. The standard deviation in the compressive strength of the three specimens varied from approximately 250 psi for average strengths of 1000 psi (coefficient of variation = 25 percent) to 500 psi for average strengths of 4000 psi (coefficient of variation = 12½ percent). These variations are larger than those usually obtained for fully consolidated specimens under laboratory conditions and may be due to the greater inhomogeneity of incompletely consolidated concrete.

The reduction in the average compressive strength of the incompletely consolidated concrete was calculated as a percentage of the fully consolidated strength at the same age. This was done for all mixes tested at 7, 28, and 91 days. In Fig. 2 the results are plotted against the corresponding average percentage voids. It will be seen that the plotted points fall fairly close to the average curve. This indicates that for a given percentage of voids the percentage reduction in compressive strength is independent of mix proportions and age. Thus, compared with the compressive strength of fully consolidated concrete at the same age, the strength of concrete containing 15 percent voids was, for example, reduced by approximately 72 percent, irrespective of the mix proportions or the age at which the tests were done. The reduction in strength due to an increase in voids up to 15 percent was much greater than that due to an increase from 15 to 30 percent.

Glanville, et al.[3] have reported the results of similar experiments on concrete of different mix proportions tested after 7 days. Stewart[4] has also published a curve showing the relationship between voids and compressive strength, although the experimental data on which it is based

TABLE 2—EFFECT OF VOIDS ON COMPRESSIVE STRENGTH

Voids, percent	Reduction in compressive strength, percent				
	Author	Glanville[3]	Stewart[4]	Author	Talbot[5]
5	30	30	36	—	—
10	56	58	58	DATUM	DATUM
15	72	72	72	36	33
20	81	85	83	57	53
25	88	90	90	73	69
30	92	—	92	82	81

is not indicated. The concordance between their results and those obtained in this investigation is shown in Table 2.

In 1921, Talbot[5] carried out a comprehensive investigation into the effects of voids on compressive strength. His data did not, however, include concrete with less than 10 percent voids. For purposes of comparison the strength of concrete with 10 percent voids was used as the datum. Thus, in Talbot's investigation, concrete with 15, 20, 25, and 30 percent voids had respectively 33, 53, 69, and 81 percent less strength than concrete containing 10 percent voids. As will be seen in Table 2 the comparative results obtained by the author in this investigation agree well with those obtained by Talbot.

Many investigations have been reported regarding the effects of intentionally entrained air on the compressive strength of concrete. In general it seems that the compressive strength, at a given water-cement ratio, of concrete containing up to about 10 percent entrained air, is reduced by approximately 5 percent for every 1 percent of air added.[6] This agrees fairly well with the effects of up to approximately 15 percent voids due to incomplete consolidation. Wright[7] has in fact concluded that the effect on compressive strength is materially the same, irrespective of whether the air is entrained intentionally in the form of numerous minute bubbles or occurs unintentionally in the form of large irregular voids. It is, however, to be noted that with increasing void content, due to incomplete consolidation, the reduction in strength for each additional 1 percent voids becomes progressively less.

The effect of air voids on the compressive strength of cellular or aerated lightweight concretes has also been investigated. However, as Taylor[8] has indicated, the relationship between bulk density and strength is greatly affected by variations in the materials and methods of manufacture. The comprehensive results given by Valore[9] for 1:4 cement-sand ratio, moist-cured cellular concrete, made by foamed and gas-forming processes, indicate, however, that the percentage reduction in strength is less than for incompletely consolidated concrete. Results given by Taylor[8] for a moist-cured 1:4 cement-sand mix, although tested at a different age, appear to confirm this.

FLEXURAL STRENGTH

The average flexural strength of beam specimens within the various density groups was ascertained. There were generally two specimens within a group, the variations in flexural strength being somewhat greater than for the fully consolidated specimens.

The percentage reduction in average flexural strength due to the presence of voids is shown in Fig. 3 for all mixes tested at the three different ages. The indications are that the reduction in flexural strength, expressed as a percentage of the fully consolidated strength at the same age, is independent of mix proportions and age. Average reductions in flexural and compressive strength are compared in Fig. 4 and it will be seen that voids have less effect on flexural than on compressive strength. There was an approximate 4 percent loss in flexural strength for every additional 1 percent voids up to 15 percent as compared to an approximate 5 percent loss in compressive strength. Like compressive strength, the average reduction in flexural strength becomes progressively less for each 1 percent increase in voids.

Little information has been published regarding the effects of incomplete consolidation on the flexural strength of concrete. Gonnerman,[10] Goldbeck,[11] Shacklock and Keene,[12] and Walker and Bloem[13] have, however, shown that for air-entrained concrete the presence of air voids has less effect on flexural than compressive strength. The investigations of Walker and Bloem[13] indicate that for concrete of the same workability, the percentage reduction in flexural strength, due to air entrainment, was about half that for compressive strength.

COMPRESSIVE VERSUS FLEXURAL STRENGTH

In Fig. 5 the flexural strength of individual beam specimens has been plotted against the average compressive strength of the two halves of the same specimen broken in flexure. Compressive and flexural strength

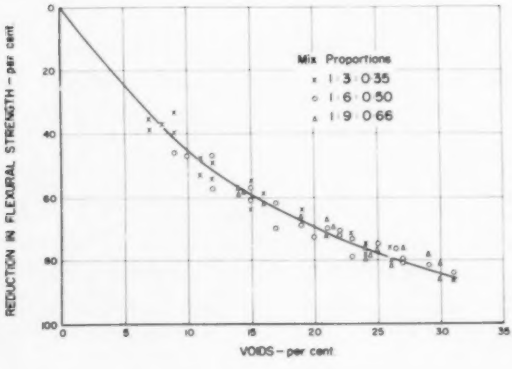


Fig. 3 — Percentage reduction in flexural strength due to incomplete consolidation

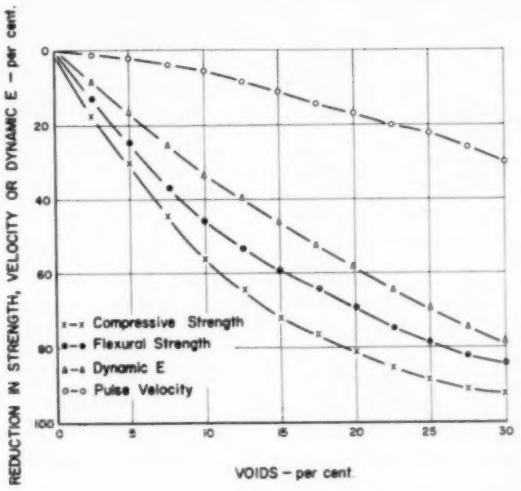


Fig. 4—Comparative effects of incomplete consolidation on reduction in compressive and flexural strength, pulse velocity, and dynamic *E*

of incompletely consolidated concrete are broadly related. The relationship was not dependent on age and mix proportions. Flexural-compressive strength ratios varied from about 0.1 at compressive strengths of 6000 psi to 0.3 at compressive strengths of 500 psi.

ULTRASONIC PULSE VELOCITY

It is generally agreed[14,15,16] that in an inhomogeneous material such as concrete a longitudinal ultrasonic pulse may circumvent air voids, cracks, and other points of weakness and take the path in which its velocity is fastest. The actual path length and thus the time taken by the pulse to pass through a concrete specimen may therefore vary. Small cavities and cracks will not necessarily cause significant changes in nomi-

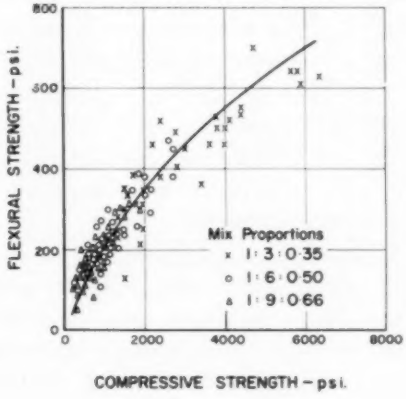


Fig. 5 — Relation between compressive and flexural strength of incompletely consolidated concrete

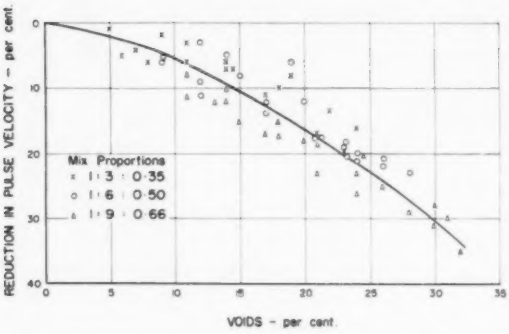


Fig. 6 — Percentage reduction in pulse velocity due to incomplete consolidation. Note that ordinate spacing is twice that of previous figures

nal pulse velocities.[17] In incompletely consolidated concrete containing large, irregular, nonuniformly distributed voids, there may, however, be significant variations in actual path lengths and therefore in nominal pulse velocities through specimens of the same mix proportions and containing the same percentage of voids. Although pulse velocity for a single test specimen was the average of five measurements on beams and ten on cubes, large differences were recorded in the average pulse velocities of three incompletely consolidated specimens of the same mix proportions, the same age, and approximately the same density. The variations were larger than those usually obtained for fully consolidated concrete under laboratory conditions and, as suggested, may be due to the greater inhomogeneity of the incompletely consolidated specimens. It is interesting to note that Whitehurst[18] and Andersen and Nerenst[19] have concluded that there was a greater variability in individual pulse velocity measurements where the concrete had suffered damage due to fire and climatic conditions such as freezing.

The average pulse velocity corresponding to the average density of specimens falling within a density group was determined in the same way as for compressive and flexural strength. The reduction in the average pulse velocity of incompletely consolidated test specimens was calculated as a percentage of the velocity in fully consolidated concrete of the same age. In Fig. 6 the results are plotted against the corresponding average percentage voids. Although the scatter is greater than for compressive and flexural strength it appears that the percentage reduction in pulse velocity for a given percentage of voids is relatively independent of mix proportions and age.

Jones[2] has mentioned that change in longitudinal pulse velocity with change in density may be calculated from a theory given by Mackenzie.[20] The theory assumes that the material has homogeneous and isotropic elastic properties, that the holes are isolated and spherical, that their total volume is small compared with the total volume of the material

TABLE 3—RATIO OF AVERAGE CHANGES IN PULSE VELOCITY AND STRENGTH DUE TO CHANGE IN VOID CONTENT

Increase in voids, percent	Reduction, percent			$\frac{\Delta V}{\Delta C}$	$\frac{\Delta V}{\Delta F}$
	Compressive strength (C)	Flexural strength (F)	Pulse velocity (V)		
5 to 10	30 to 56	24 to 46	2 to 5	0.12	0.14
15 to 20	72 to 81	59 to 69	11 to 17	0.67	0.60
25 to 30	88 to 92	78 to 84	22 to 30	2.00	1.33

but that the number of holes is large. On the basis of this theory Jones calculated that a change in density of 10 percent causes a change of approximately 6.5 percent in pulse velocity, as compared with a figure of 12 percent which he obtained experimentally from concrete cores cut from a road slab. The results of the present investigation indicate an average reduction of approximately 5 percent in pulse velocity due to the presence of 10 percent voids. The rate of reduction in velocity increases, however, with increasing void content, an increase in voids from 10 to 20 percent resulting for example in a 12 percent decrease in pulse velocity as compared to a 5 percent decrease for the first 10 percent voids.

In Fig. 4 the average percentage of reductions in pulse velocity and strength, due to the presence of voids, are compared. It is clearly evident that voids due to incomplete consolidation have much less effect on pulse velocity than on compressive and flexural strength. Thus, 5 percent voids caused a reduction of approximately 2 percent in pulse velocity compared with reductions of 30 and 24 percent, respectively, in compressive and flexural strength. Thirty percent voids resulted in a reduction of approximately 92 percent in compressive strength and 84 percent in flexural strength but only 30 percent in pulse velocity.

PULSE VELOCITY VERSUS COMPRESSIVE AND FLEXURAL STRENGTH

It has been shown, particularly at low percentages of void contents, that changes in the degree of consolidation of concrete have much greater effect on strength than on pulse velocity. This may be attributed to the fact that whereas strength is greatly affected by voids, an ultrasonic pulse tends to circumvent voids with a consequently small comparative effect on the nominal pulse velocity. It is therefore of interest to observe the relationships between pulse velocity and the strength of incompletely consolidated concrete.

In Fig. 7 and 8 the average pulse velocity through individual incompletely consolidated test specimens has been plotted against their compressive and flexural strengths. There is a broad relationship between pulse velocity and the strength of incompletely consolidated concrete. The average curves indicate that in contradistinction to fully consolidated concrete, differences in mix proportions did not have any significant

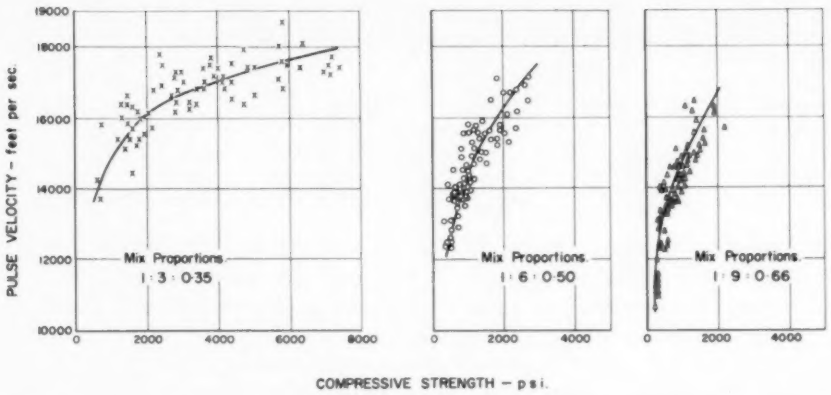


Fig. 7—Relation between compressive strength and pulse velocity of incompletely consolidated concrete

effect on the pulse velocity-strength relationships. This may be due to the predominating effects of the voids. It is, however, evident that at high void contents and therefore low strengths, pulse velocity is more sensitive to changes in strength than at low void contents and therefore higher strengths. In Table 3, this is indicated by the ratio of change in pulse velocity to change in strength.

The percentage reductions in pulse velocity and strength, due to a change in voids are compared in Fig. 9. It will be seen, particularly at high void contents, that pulse velocity is on the average more sensitive to changes in flexural than in compressive strength. (A recent paper[21] by the author entitled "Effects of Age and Water-Cement Ratio Upon the

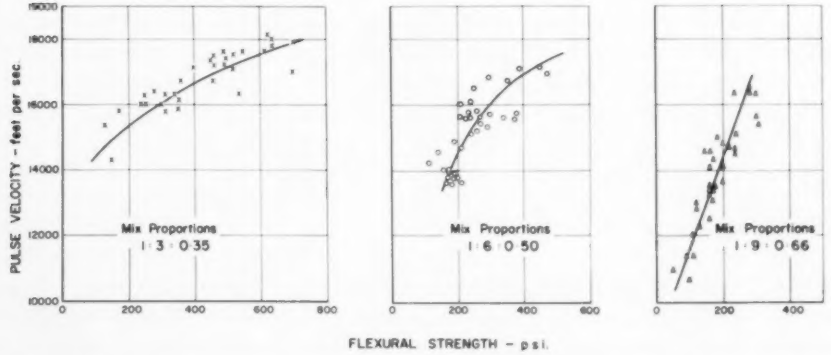


Fig. 8—Relation between flexural strength and pulse velocity of incompletely consolidated concrete

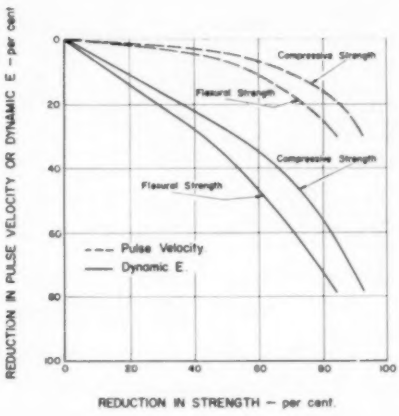


Fig. 9—Comparative effects of incomplete consolidation on relations between strength and pulse velocity and between strength and dynamic *E*

Relation Between Ultrasonic Pulse Velocity and the Compressive Strength of Concrete" may be of interest to readers.)

DYNAMIC MODULUS OF ELASTICITY

Variations in the dynamic modulus of elasticity of incompletely consolidated beams of the same mix proportions, and approximately the same bulk density, were of the same order as for fully consolidated test specimens. This is probably because in the measurement of resonant frequency the whole test specimen is vibrated, thus giving a good indication of its average elastic properties.

The average dynamic *E* corresponding to an average density was determined in the same way as for flexural strength, each result being generally the average of tests on two specimens. The reduction in the

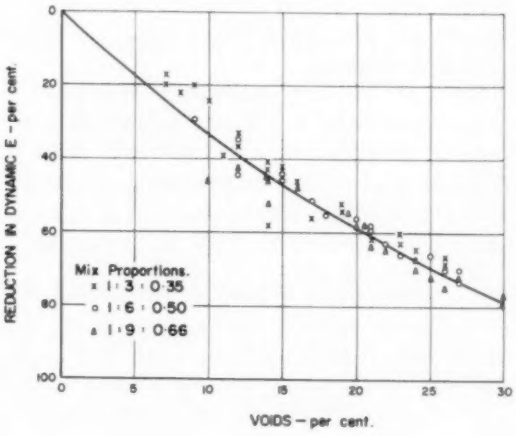


Fig. 10—Percentage reduction in dynamic *E* due to incomplete consolidation

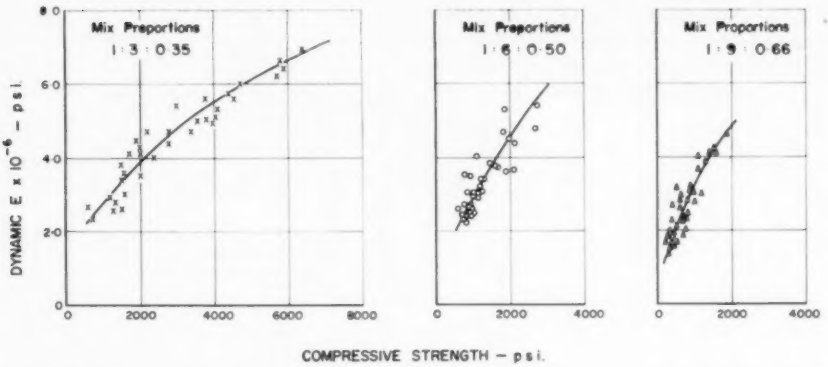


Fig. 11—Relation between compressive strength and dynamic *E* of incompletely consolidated concrete

average dynamic *E* of incompletely consolidated specimens was calculated as a percentage of the dynamic *E* for fully consolidated concrete of the same age. In Fig. 10 the results for all mixes tested at 7, 28, and 91 days are plotted against the corresponding average percentage voids. The plotted points fall fairly close to the average curve, thus indicating that the relationship between the percentage reduction in dynamic *E* and the percentage of voids is independent of mix proportions and age.

Reference to Fig. 4 also indicates clearly that the effects of voids on dynamic *E* is much greater than on pulse velocity, e.g., 5 percent voids reduced dynamic *E* by approximately 16 percent and pulse velocity by only about 2 percent while 25 percent voids reduced dynamic *E* by 69 percent and pulse velocity by 22 percent. The percentage reduction in dynamic *E* is more comparable with reductions in compressive and flexural strength. For 5 percent voids, there were average reductions in dynamic *E*, flexural strength, and compressive strength of 16, 24, and 30 percent, respectively; for 30 percent voids the reductions were 78, 84, and 92 percent.

Cordon[22] has reported about 20 percent reduction in static *E* for concrete containing 8 percent entrained air while Graf[23] mentions a 70 percent reduction in static E for moist cured cellular cement-sand specimens made by various processes and containing approximately 31 percent voids. These results are of the same order as the reductions in dynamic *E* due to voids caused by incomplete consolidation.

DYNAMIC E VERSUS COMPRESSIVE AND FLEXURAL STRENGTH

In Fig. 11 and 12 the dynamic *E* of individual incompletely consolidated beam specimens has been plotted against their compressive and flexural strengths. There is a good relationship between dynamic *E* and the strength of concrete containing voids due to incomplete consoli-

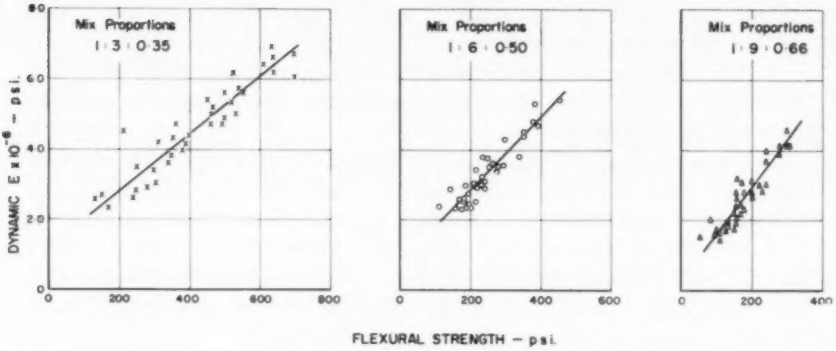


Fig. 12—Relation between flexural strength and dynamic *E* of incompletely consolidated concrete

dation. The average curves indicate that the relationships are not necessarily independent of mix proportions.

As shown in Fig. 9, for a given percentage reduction in strength, due to voids, the percentage reduction in dynamic *E* is greater than the percentage reduction in pulse velocity. Thus a 20 percent reduction in flexural and compressive strength is accompanied by a respective reduction of approximately 14 and 10 percent in dynamic *E*, while the corresponding reduction in pulse velocity was approximately 2 and 1 percent. For an 80 percent reduction in flexural and compressive strength there was a corresponding reduction in dynamic *E* of approximately 72 and 55 percent respectively while the pulse velocity was only 24 and 16 percent. As in the case of pulse velocity, dynamic *E* is somewhat more sensitive to changes in strength at high void levels than at low void levels. Dynamic *E* is also more sensitive to changes in flexural than in compressive strength.

CONCLUSIONS

The following are conclusions regarding the effects on concrete of voids, due to incomplete consolidation.

1. Reductions in compressive strength, flexural strength, pulse velocity, and dynamic *E*, when expressed as a percentage of the fully consolidated values at the same age, are not significantly affected by differences in mix proportions or age. In the case of pulse velocity, scatter about the average curve was greater than for strength and dynamic *E*.

2. Voids have more effect on compressive than flexural strength, e.g., 5 percent voids reduced compressive strength by approximately 30 percent while the same amount of voids only reduced the flexu-

ral strength by 24 percent; for 25 percent voids the reductions were 88 and 78 percent, respectively.

3. The compressive and flexural strength of incompletely consolidated concrete are broadly related. The relationship was independent of mix proportions and age.

4. Voids due to incomplete consolidation have much less effect on pulse velocity than on compressive and flexural strength. The presence of 5 percent voids caused reductions of approximately 30 and 24 percent, respectively, in compressive and flexural strength but only a 2 percent reduction in pulse velocity. For 30 percent voids the reductions in compressive strength, flexural strength, and pulse velocity were 92, 84, and 30 percent, respectively.

5. The effects of voids on dynamic E are much greater than on pulse velocity, the percentage reduction in dynamic E being therefore much more comparable with percentage reduction in strength. For 5 percent voids, reductions in compressive strength, flexural strength, and dynamic E were 30, 24, and 16 percent, respectively. At 30 percent voids the reductions were 92, 84, and 78 percent.

6. There is a broad relationship between pulse velocity and the compressive and flexural strength of incompletely consolidated concrete. The same applies to dynamic E and strength, the relationship being, however, somewhat more reliable than for pulse velocity.

For a given percentage reduction in strength there was also, on the average, a much greater percentage reduction in dynamic E than in pulse velocity, e.g., a 20 percent reduction in flexural and compressive strength was accompanied by reductions of 14 and 10 percent, respectively, in dynamic E whereas the corresponding reductions in pulse velocity were approximately 2 and 1 percent.

REFERENCES

1. "Methods of Testing Concrete," *British Standard* 1881:1952, British Standards Institution, London, 1952.

2. Jones, R., and Gatfield, E., "Testing Concrete by an Ultrasonic Pulse Technique," *Road Research Technical Paper* No. 34, Her Majesty's Stationery Office (London), 1955.

3. Glanville, W. H.; Collins, A. R.; and Matthews, D. D., "The Grading of Aggregates and Workability of Concrete," *Road Research Technical Paper* No. 5, Her Majesty's Stationery Office (London), 1938.

4. Stewart, D. A., *The Design and Placing of High Quality Concrete*, E. and F. N. Spon, Ltd., London, 1951, p. 90.

5. Talbot, A. N., "A Proposed Method of Estimating the Density and Strength of Concrete and of Proportioning the Materials by the Experimental and Analytical Consideration of the Voids in Mortar and Concrete," *Proceedings, ASTM*, V. 21, 1921, p. 940.

6. Walker, S., and Bloem, D. L., "Design and Control of Air-entraining Concrete," *Publication* No. 60, National Ready Mixed Concrete Association, Washington, D.C., Dec. 1955.

7. Wright, P. J., "Entrained Air in Concrete," *Proceedings*, Institution of Civil Engineers (London), Part 1, May 1953, pp. 337-358.

8. Taylor, W. H., "Lightweight Concrete," Australian and New Zealand Association for the Advancement of Science, Canberra Conference, Jan. 1954.

9. Valore, R. C., "Cellular Concretes," ACI JOURNAL, V. 25, No. 10, June 1954 (*Proceedings* V. 50), p. 820.

10. Gonnerman, H. F., "Tests of Concretes Containing Air-Entraining Portland Cements or Air-Entraining Materials Added to Batch at Mixer," ACI JOURNAL, V. 15, No. 6, June 1944 (*Proceedings* V. 40), p. 477.

11. Goldbeck, A. T., "Effect of Air Entrainment on Stone Sand Concrete," ACI JOURNAL, V. 17, No. 6, June 1946 (*Proceedings* V. 42), p. 649.

12. Shacklock, G. W., and Keene, P. W., "Comparison of the Compressive and Flexural Strengths of Concrete with and without Entrained Air," *Civil Engineering and Public Works Review* (London), V. 54, No. 631, Jan. 1959, p. 77.

13. Walker, S., and Bloem, D. L., "Studies of Flexural Strength of Concrete," Part 1, *Joint Research Laboratory Publication* No. 3, National Sand and Gravel Association, National Ready Mixed Concrete Association, Washington, D. C., July 1956.

14. Spencer, R. W., and Laverty, B. R., "Appraising the Quality and Performance of Concrete by Pulse Velocity Measurements," *Bulletin* No. 206, Highway Research Board, 1959, p. 46.

15. Oleson, C. C., "Evaluation of Pulse Velocity Tests Made with Portland Cement Association Soniscopes," *Bulletin* No. 206, Highway Research Board, 1959, p. 64.

16. Woods, K. B., and McLaughlin, J. F., "Application of Pulse Velocity Tests to Several Laboratory Studies of Materials," *Bulletin* No. 206, Highway Research Board, 1959, p. 14.

17. "The Ultrasonic Testing of Concrete," *Magazine of Concrete Research* (London), V. 8, No. 24, Nov. 1956, p. 165.

18. Whitehurst, E. A., "Soniscope Tests Concrete Structures," ACI JOURNAL, V. 22, No. 6, Feb. 1951 (*Proceedings* V. 47), pp. 433-444.

19. Andersen, J., and Nerenst, P., "Wave Velocity in Concrete," ACI JOURNAL, V. 23, No. 8, Apr. 1952 (*Proceedings* V. 48), pp. 613-635.

20. Mackenzie, J. K., "The Elastic Constants of a Solid Containing Spherical Holes," *Proceedings*, Physical Society (London), V. 63, No. 1, 1950, p. 2.

21. Kaplan, M. F., "The Effects of Age and Water-Cement Ratio Upon the Relation Between Ultrasonic Pulse Velocity and Compressive Strength of Concrete," *Magazine of Concrete Research* (London), V. 11, No. 32, July 1959, pp. 85-92.

22. Cordon, W. A., "Entrained Air—a Factor in the Design of Concrete Mixes," ACI JOURNAL, V. 17, No. 6, June 1946 (*Proceedings* V. 42), pp. 605-620.

23. Graf, O., *Foam Concrete, Gas Concrete, Light Lime Concrete*, Konrad Wittwer, Stuttgart, 1949.

Received by the Institute Sept. 8, 1959. To be presented at the ACI 56th annual convention, New York, Mar. 16, 1960. Title No. 56-47 is a part of copyrighted Journal of the American Concrete Institute, V. 31, No. 9, Mar. 1960 (Proceedings V. 56). Separate prints are available at 60 cents.

American Concrete Institute, P. O. Box 4754, Redford Station, Detroit 19, Mich.

Discussion of this paper should reach ACI headquarters in triplicate by June 1, 1960, for publication in the Part 2, September 1960 JOURNAL.

Title No. 56-48

Bearing Capacity of Concrete Blocks

By TUNG AU and DONALD L. BAIRD

Laboratory tests were conducted to determine the bearing capacity of square concrete blocks whose area is 2 to 16 times the contact area and whose depth equals either full or half width of the block. Two concrete mixes with different maximum aggregate size were used for a total of 60 test specimens. The test results were plotted in dimensionless coordinates, with the ratio of bearing capacity to unconfined compressive cylinder strength as ordinate and the ratio of block area to contact area as abscissa. A rational interpretation of the test results is suggested.

■ WHEN A CONCRETE BLOCK IS SUBJECTED to a localized load, the bearing capacity of the material is known to increase due to the confining pressure in the neighborhood of the contact area. Load tests of concrete blocks by Meyerhof[1] and Shelson[2] indicated that failures of concrete under base plates are similar to those observed in triaxial compression tests. Meyerhof developed a rational analysis for strip and circular base plates on large blocks and used it to check the results of model tests. Shelson conducted his tests on concrete cubes through base plates of small to moderate sizes in comparison with the area of the block. The present paper reports the results of an investigation on the bearing capacity of concrete blocks loaded through relatively large base plates, i.e., small ratios of block area to contact area.

There are numerous examples in engineering practice in which better utilization of the high bearing capacity of concrete under confined contact area is desired. For large ratios of block area to contact area, however, the problem is complicated by the fact that such footings are usually embedded on soil of relatively low modulus of elasticity. The application of results of laboratory tests to different field conditions requires a great deal of judgment based on experience. On the other hand, the cases involving relatively small ratios of block area to contact area more or less simulate the actual conditions such as building columns on concrete pedestals, bridge bearings on concrete piers, and foundations of some hydraulic structures.

LOAD TESTS OF CONCRETE BLOCKS

Preliminary considerations

In the study of concrete in triaxial compression, Richart, Brandtzeag, and Brown[3] found that the numerical results of the tests approach an agreement with the internal friction theory of sliding failure. Load tests of concrete blocks by Meyerhof exhibited sliding failure in concrete due to the formation of a distinctly separate cone under the circular base plate. Although the formation of an inverted pyramid in concrete under small base plates was also observed by Shelson, only the appearance of internal pyramid was noted in concrete cubes under larger base plates.

Since the present study covers the range of relatively large base plates, preliminary tests were conducted on concrete cubes to determine the variable factors involved. It was felt, and later confirmed by the preliminary tests, that the splitting of concrete block prior to the formation of a separate inverted pyramid under the base plate could be caused by secondary bending due to the uneven bottom surface of the concrete block. When the bottom of the concrete block was embedded in plaster of Paris on a steel shoe plate, the formation of a separate inverted pyramid invariably occurred under the contact area. Consequently, the internal friction theory of sliding failure was used as a working hypothesis. It was realized, however, that for a specimen with small ratio of block area to contact area, the inverted pyramid would penetrate through a relatively great depth. If the depth of the concrete block is reduced, the mode of failure may be affected. A series of tests of square blocks with depth equal to half width was therefore included in the subsequent study of such effects.

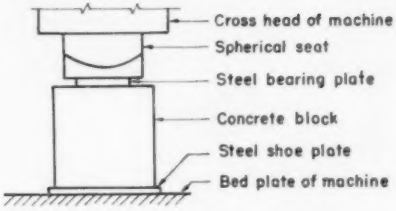
The choice of maximum size of aggregate in concrete was based on two considerations. On the one hand, concrete with small aggregates may appear to simulate better the scaling down of an actual pedestal or footing. On the other hand, the angle of internal friction of concrete depends on the maximum size of aggregate in concrete. Hence, two different mixes were used.

Another factor which may influence the test results is the flexibility of the base plate if the load is placed over only a part of the base plate. This is borne out by the tests reported by Shelson which consisted of

ACI member and registered professional engineer **Tung Au** is an associate professor of civil engineering, Carnegie Instititute of Technology, Pittsburgh. He was previously on the staff of the University of Detroit. In addition to his activities as an educator he has also done design work for a number of engineering and architectural firms.

Donald L. Baird is a construction engineer with H. C. Howells and Son Co., Youngstown, Ohio. He received his masters degree from Carnegie Institute of Technology in 1959 where he also worked as a graduate assistant in the department of civil engineering.

Fig. 1—Loading details



loading 8-in. cubes on a confined area of 1 sq in. through base plates of 1, 2, 4, and 9 sq in. To eliminate unnecessary complications, loads were applied to concrete blocks on full areas of base plates. Thus the terms contact area and loaded area are synonymous in this paper.

Test specimens

The specimens were cast from two mixes of concrete designated as Mix 1 and 2. The materials for Mix 1 consisted of portland cement and well graded sand which ranged from fine sand to pea gravel screened through a sieve of 0.25-in. openings. The mix had a 1:2.5 cement-sand ratio and a water-cement ratio of 0.5 by weight. Mix 2 was ordered from a ready-mixed concrete plant and contained maximum size aggregate of ½ in.

Two series of specimens were cast from each mix. Series A consisted of 8-in. cubes and Series B included 8 x 8 x 4 in. blocks. Four standard 6 x 12-in. cylinders were cast from each mix to determine the unconfined compressive strength. An electric vibrator was used while the concrete was cast in the forms. All blocks and cylinders were properly cured at ±70 F for 28 days.

For both Series A and B from each mix, square steel base plates were placed on top of the concrete blocks in plaster of Paris. The sides of the base plates were 5.67, 4.00, 3.27, 2.83, 2.31, and 2.00 in. to provide ratios of block area to contact area equal to 2, 4, 6, 8, 12, and 16, respectively. The plate thickness of the first four sizes was ⅜ in. while that of the last two sizes was ¼ in. The concrete blocks were embedded in plaster of Paris on steel shoe plates ¼ in. thick which provide smooth bottom surfaces.

For each mix, two identical companion specimens for Series A and three for Series B were tested. The reason for having only two companion specimens for Series A was that the results of the preliminary tests could be used for check if a large discrepancy should occur.

Test procedure and results

The concrete blocks were tested in an Amsler hydraulic compression testing machine of 400,000 lb capacity. A spherical seat was placed on top of the base plate to insure even load distribution. The typical loading detail is shown in Fig. 1. Loads were applied at the rate of 1000 lb per sec or less until failure of the blocks.

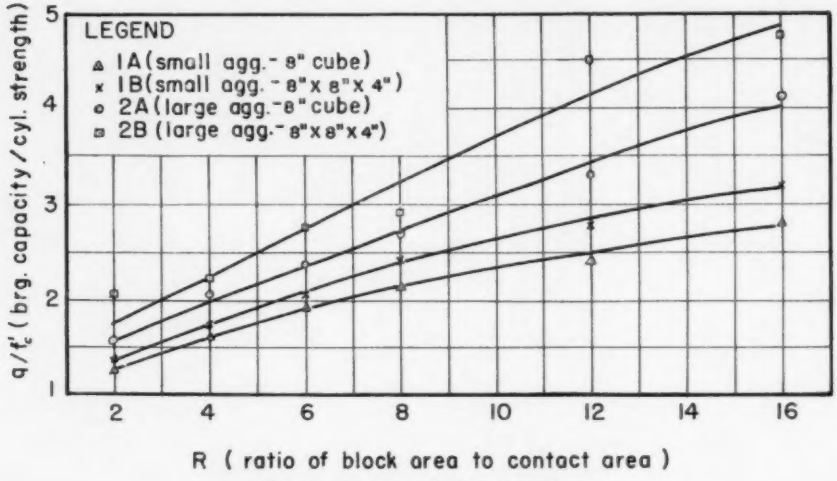


Fig. 2—Summary of test results

Results of the tests are summarized in Table 1 which shows the ultimate loads on concrete blocks in kips. The maximum compressive loads on the concrete cylinders from Mix 1 and 2 were also recorded and the unconfined compressive strength f_c' was found to be 8050 psi and 4500 psi, respectively. The ultimate bearing capacity q in psi for various ratio R of block area to contact area is given in Table 2, and the dimensionless relationship between q/f_c' and R is shown in Fig. 2.

Modes of failure

Fig. 3 shows the typical appearance of the cubes in Series A at failure. A vertical crack started at the top of the block progressed downward indicating splitting due to sliding failure. The maximum load was usually reached shortly after the crack appeared, and then the load carrying capacity immediately dropped to a negligible amount. Fig. 4 shows the pyramids taken from the cubes after failure. In each case, the pyramid was forced down by the applied load as failure was im-

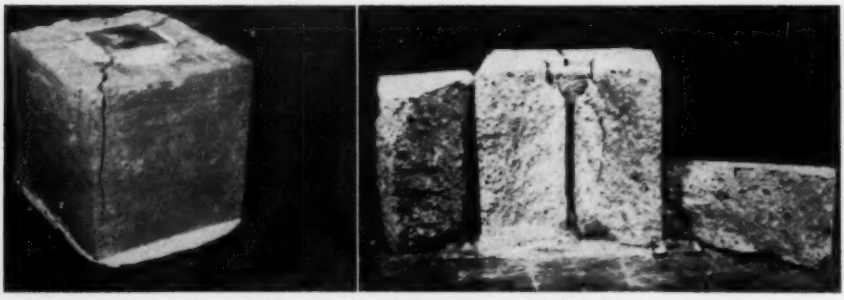


Fig. 3—Concrete cubes in Series A after failure

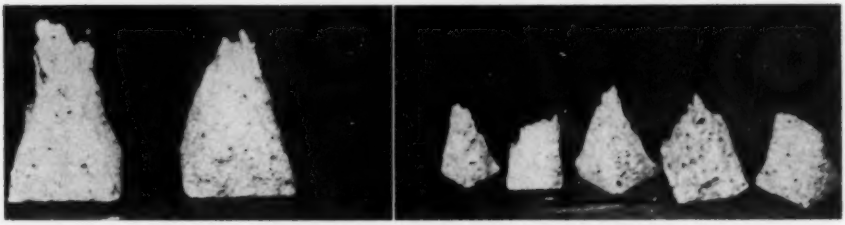


Fig. 4—Pyramid separated from cubes in Series A

pending. Pyramids for various ratios of block area to contact area are represented.

Fig. 5 shows the typical failure of blocks from Series B with a depth to width ratio of ½. These blocks were split radially and, in most cases,

TABLE 1—ULTIMATE LOADS ON CONCRETE BLOCKS IN KIPS

Types of Specimens			R = ratio of block area to contact area					
			2	4	6	8	12	16
Small aggregate $f_c' = 8050$ psi	8-in. cubes	Specimen a	315	210	168	142	91	88
		Specimen b	345	210	162	134	115	92.5
		Average	330	210	165	138	103	90.25
	8 x 8 x 4-in. blocks	Specimen a	370	208	143	166	141	102.5
		Specimen b	360	238	187	130	122	101
		Specimen c	330	232	188	171	96	106.5
		Average	353.3	226	172.7	155.7	119.7	103.3
Large aggregate $f_c' = 4500$ psi	8-in. cubes	Specimen a	221	146	107.5	98	75	72.5
		Specimen b	232	152.5	122.5	95	84	78
		Average	226.5	149.3	115	96.5	79.5	75.3
	8 x 8 x 4-in. blocks	Specimen a	300	153	130	103	102	92
		Specimen b	283	148	107	98	114	80
		Specimen c	309	180	163	113	110	85
		Average	297	160	133.3	104.7	108.7	85.7

TABLE 2—BEARING CAPACITY OF CONCRETE BLOCKS

Quantity	Type of Specimens		R = ratio of block area to contact area					
			2	4	6	8	12	16
Average bearing capacity q, psi	Small aggregate $f_c' = 8050$ psi	8-in. cubes	10300	13130	15470	17250	19320	22600
		8 x 8 x 4-in. blocks	11020	14120	16190	19450	22420	25850
	Large aggregate $f_c' = 4500$ psi	8-in. cubes	7080	9330	10750	12070	14920	18700
		8 x 8 x 4-in. blocks	9290	10020	12500	13080	20400	21410
Ratio of q/f_c'	Small aggregate $f_c' = 8050$ psi	8-in. cubes	1.28	1.63	1.92	2.14	2.40	2.80
		8 x 8 x 4-in. blocks	1.37	1.76	2.05	2.42	2.79	3.21
	Large aggregate $f_c' = 4500$ psi	8-in. cubes	1.57	2.07	2.39	2.68	3.32	4.15
		8 x 8 x 4-in. blocks	2.06	2.23	2.78	2.90	4.53	4.76

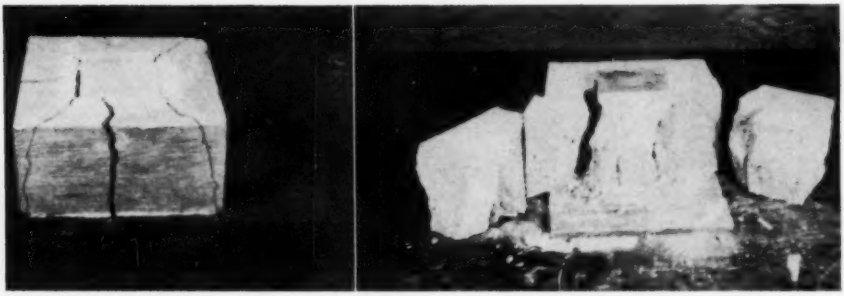


Fig. 5—Concrete blocks in Series B after failure

no clear-cut pyramids were observed. Instead, there appeared to be a vertical core of concrete with a narrowed section at the middepth, which was so small in some cases that practically two upside down pyramids were formed. The cracks in Series B appeared first at the bottom of the sides and progressed upward. This seemed to indicate that the splitting was caused by radial pressure resulting from large deformation of concrete under the base plate.

CORRELATION OF TEST DATA

Failure of the 8-in. cubes

As shown in Fig. 3, the failure of the 8-in. cubes was caused by the splitting of the blocks along a diagonal plane. This splitting was preceded by the formation of an inverted pyramid which was forced down by the applied bearing pressure. The bearing pressure q which produced such a failure may be estimated approximately by the following equation:

$$q = (2s_o + K f_t) \cot \alpha$$

The notations used in this equation as well as its derivation are given in the appendix. The equation may also be expressed in dimensionless form as follows:

$$\frac{q}{f_c'} = \left(\frac{2s_o}{f_c'} + \frac{Kf_t}{f_c'}\right) \cot \alpha \quad \text{..... (1)}$$

If all quantities on the right hand side of Eq. (1) are known or measured, q/f_c' may be predicted.

Unfortunately, the apex angles of the pyramids from the load tests could not be accurately measured because the sides of the pyramids were not perfectly symmetrical. It was found that the half apex angles α varies from 19 to 25 deg approximately. Although the average value of α is greater for concrete with smaller aggregates, the results are too scattered to justify more refined differentiation. As a matter of fact, both cot α and the term K in Eq. (1) are sensitive to small change in

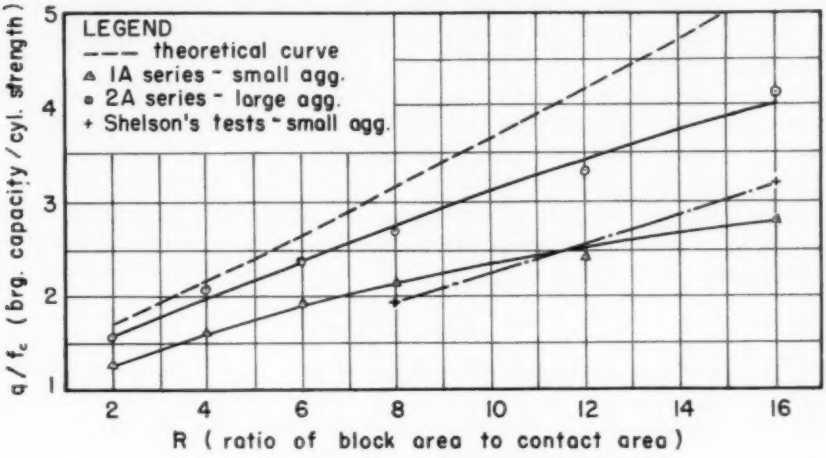


Fig. 6—Comparative study of results for 8-in. cubes

the value of α, and unless the average is obtained from a sufficiently large number of fairly uniform results, such conclusion may be misleading. For the purpose of estimating q/f_c', the median of 22 deg is adopted for concrete with both mixes.

In view of the uncertainties just cited, no attempt was made to determine exactly the values of s_o and f_t. Again, for the purpose of approximation, s_o/f_c' is taken to be 0.23 from Fig. A-1, and f_t/f_c' is assumed to be 0.1, a value often used to estimate the ultimate tensile strength of concrete.

By substituting these empirical and assumed values into Eq. (1), q/f_c' can be evaluated for various values of R which are implicitly expressed in the term K. A theoretical curve based on such evaluation is shown in Fig. 6. It should be emphasized again that with several empirical constants, Eq. (1) does not predict the bearing capacity accurately but provides a useful framework to correlate experimental data rationally.

Fig. 6 also shows the experimental data of concrete cubes as well as the theoretical curve. The test results on cubes with small aggregates by Shelson for $R = 8$ and 16 are also included. While the test results of concrete cubes with Mix 1 agree well with those by Shelson in this range of R, the results of concrete cubes with Mix 2 are closer to the theoretical values.

Failure of 8 x 8 x 4-in. blocks

In examining the specimens in this series after failure, it was noted that no clear cut pyramids were formed. It appeared that the retardation of the formation of pyramids to a certain extent also resists the

sliding failure. Thus, the experimental results of the bearing capacity for the blocks in Series B are consistently higher than those for the cubes in Series A.

There were other factors which influenced the test results of these relatively thin blocks, such as the possible bending of a block as a cantilever with pressure acting at the bottom, and the restraint of the radial splitting due to friction between the bottom of the block and the bed plate of the testing machine. The comparatively erratic results for blocks in Series B might be accounted for by the consideration of these factors.

CONCLUSION

The paper has presented the results of load tests of square concrete blocks with the ratio of block area to contact area ranging from 2 to 16. The effects of the maximum aggregate size and the depth of the blocks have also been considered.

Although the tests confirm the fact that the bearing capacity of concrete under confined contact area is greater than the unconfined compressive strength, they also show pointedly the influence of a multiple of variable factors. The test results as well as the theoretical interpretation should not be generalized beyond the range of variables intended for this study. Any revision toward higher allowable bearing pressure in design codes such as the ACI Building Code[4] must be made with conservatism. More drastic departure from the current design values can be made only after more thorough investigations of all factors involved in the problem.

REFERENCES

1. Meyerhof, G. G., "The Bearing Capacity of Concrete and Rock," *Magazine of Concrete Research* (London), V. 4, No. 12, Apr. 1953, pp. 107-116.

2. Shelson, William, "Bearing Capacity of Concrete," ACI JOURNAL, V. 29, No. 5, Nov. 1957 (*Proceedings* V. 54), pp. 405-414.

3. Richart, F. E.; Brandtzeag, A.; and Brown, R. L., "A Study of the Failure of Concrete Under Combined Compressive Stresses," *Bulletin* No. 185, University of Illinois Engineering Experiment Station, Nov. 1928.

4. ACI Committee 318, "Building Code Requirements for Reinforced Concrete (ACI 318-56)," ACI JOURNAL, V. 27, No. 9, May 1956 (*Proceedings* V. 52), Section 305, p. 927.

5. Tschebotarioff, Gregory P., *Soil Mechanics, Foundations and Earth Structures*, McGraw-Hill Book Co., Inc., New York, 1951, pp. 132-134.

APPENDIX

Notations

A = area of concrete in diagonal plane outside of the inverted pyramid [Fig. A-3(a)]

B = width of square base plate

f_b = stress due to bending alone

f_t = direct tensile stress

f_t = tensile stress due to combined effects of direct tension and bending [Fig. A-3(a)]
f_c' = unconfined compressive strength of standard cylinder
F = horizontal splitting force [Fig. A-3(b)]
H = depth of concrete block
I = moment of inertia of area A about its centroidal axis [Fig. 9(a)]
K = a function of A, y, and I as defined in Eq. (A3)
L = width of square concrete block
p = pressure normal to shearing surface
p_h = horizontal splitting pressure
p_1 = vertical principal stress in triaxial compression
p_2 = horizontal principal stresses in triaxial compression
q = bearing pressure under base plate
R = ratio of block area to contact area
s = shearing resistance per unit area of shearing surface
s_o = shearing resistance per unit area for $p = 0$
y = depth from top of block to the neutral axis of bending
α = half of the apex angle on a vertical plane passing through the apex of the inverted pyramid [Fig. A-2]
θ = compliment of angle α [Fig. A-2]
ϕ = angle of internal friction

Internal friction theory of sliding failure

If an infinitesimal element is taken from a body under triaxial compression as shown in Fig. A-1, the normal pressure and the shearing stress along a plane inclined at an angle with the vertical direction can be obtained by the construction of Mohr's circle. When the results of a group of concrete tests are represented by Mohr's circles, they define the limiting curve or the envelope of these circles. Limiting curves for different mixes of concrete were presented by Richart, Brandtzeag, and Brown (p. 78, Reference 3), and are reproduced in dimensionless coordinates in Fig. A-1. It may be noted that the limiting curves for concrete are not linear but can be approximated by straight lines without introducing serious error. For a given mix of concrete, the shearing strength may be represented by:

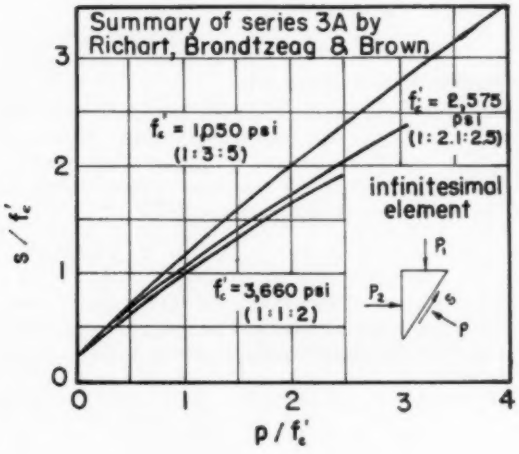


Fig. A-1—Relation between normal and shearing stresses in triaxial compression tests of concrete

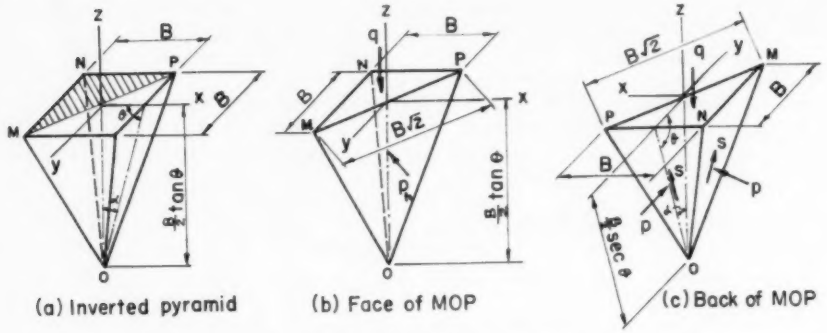


Fig. A-2—Inverted pyramid formed under bearing plate

$$s = s_o + p \tan \phi \qquad \text{(A1)}$$

where ϕ decreases with increasing normal pressure. The plane of least resistance to shearing along it will correspond to a minimum value of p_h which can produce sliding failure. It can be demonstrated[5] that this minimum value occurs when $\theta = 45 \text{ deg} + \phi/2$ or $\alpha = 45 \text{ deg} - \phi/2$.

A similar situation exists in an inverted pyramid developed under the contact area in a concrete block as shown in Fig. A-2(a). If half of the pyramid cut through by a diagonal plane is considered as a free body, the state of stress in the element is shown in Fig. A-2(b) and A-2(c), in which p_h is the horizontal pressure causing splitting of the block. From the conditions of equilibrium of vertical and horizontal forces, the following equations are obtained:

$$p_h \tan \theta + s - p \tan \theta = 0$$

$$-q + s \tan \theta + p = 0$$

Solving for s and p and substituting them into Eq. (A1), one obtains:

$$q = \frac{s_o + p_h(\sin^2 \theta \tan \phi + \sin \theta \cos \theta)}{\sin \theta \cos \theta - \cos^2 \theta \tan \phi}$$

For the critical angle $\theta = 45 \text{ deg} + \phi/2$ or $\alpha = 45 \text{ deg} - \phi/2$, for which q will produce sliding failure,

$$q = 2s_o \cot \alpha + p_h \cot^2 \alpha \qquad \text{(A2)}$$

Application to 8-in. cubes

Fig. A-3(a) shows the typical failure of an 8-in. cube splitting along a diagonal plane. The splitting was preceded by the formation of an inverted pyramid which was forced down by the applied bearing pressure. The splitting force F in Fig. A-3(b) is the resultant of the horizontal splitting pressure p_h acting on the inverted pyramid and equals

$$F = \frac{\sqrt{2}}{4} B^2 p_h \cot \alpha$$

This force produces combined direct tension and bending in the concrete block, with a stress distribution as shown in Fig. A-3(c) when the bearing pressure is low. The maximum tensile stress at the top of the block can be computed as follows:

$$f_t = \frac{F}{A} + \frac{F\,[y - (B/6) \cot \alpha]y}{I}$$

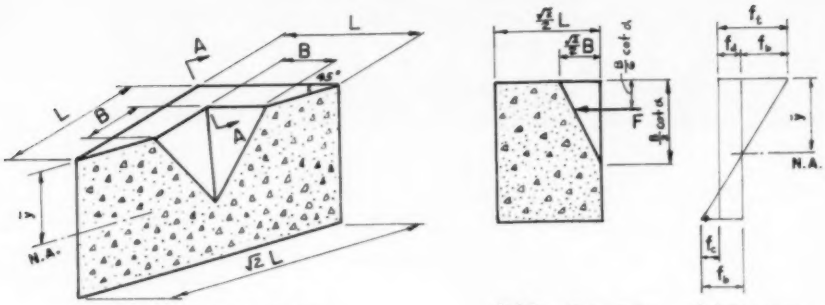


Fig. A-3—Splitting of 8-in. cube

$$f_t = (p_h/K) \cot \alpha \quad \text{(A3)}$$

in which

$$A = \sqrt{2}\,[LM - (B^2/4) \cot \alpha]$$

$$y = \frac{LH^2/2 - (B^3/24) \cot^2 \alpha}{LH - (B^2/4) \cot \alpha}$$

$$I = \sqrt{2}\,[LH^3/12 + LH\ (y - H/2)^2 - (5/576)\ B^4 \cot^2 \alpha]$$

$$\frac{1}{K} = \frac{\sqrt{2}\ B^2}{4}\left\{\frac{1}{A} + \frac{[y - (B/6) \cot \alpha]\ y}{I}\right\}$$

By substituting Eq. (A3) into Eq. (A2), the following expression is obtained:

$$q = 2s_o \cot \alpha + Kf_t \cot \alpha$$

or

$$\frac{q}{f_c'} = \left(\frac{2s_o}{f_c'} + \frac{Kf_t}{f_c'}\right) \cot \alpha \quad \text{(1)}$$

At high bearing pressure, the stress distribution along the depth of the block becomes nonlinear and the relation between f_t and p_h no longer remains the same as Eq. (A3). However, Eq. (1) may still be used if f_t represents a fictitious stress distribution corresponding to the strain at rupture.

The approximate character of Eq. (1) is fully realized. Furthermore, it is applicable only to regions remote from the area of load application in accordance with St. Venant's principle. Nevertheless, it provides a rational basis for relating the empirical constants.

Received by the Institute June 18, 1959. Title No. 56-48 is a part of copyrighted Journal of the American Concrete Institute, V. 31, No. 9, Mar. 1960 (Proceedings V. 56). Separate prints are available at 50 cents each.

American Concrete Institute, P.O. Box 4754, Redford Station, Detroit 19, Mich.

Discussion of this paper should reach ACI headquarters in triplicate by June 1, 1960, for publication in Part 2, September 1960 JOURNAL.

CONCRETE BRIEFS

Notes from Field and Office

Inhibiting Alkali-Aggregate Reactions with Barium Salts 881

Ultimate Strength Design of Rectangular Cross Sections Under Bending with Tensile Steel Only 884

Load Factors 886

Inhibiting Alkali-Aggregate Reaction with Barium Salts

By W. C. HANSEN*

McCOY AND CALDWELL[1] SHOWED that lithium salts were effective in decreasing expansions caused by alkali-aggregate reaction in mortar specimens. It is generally agreed that these expansions are caused by Na_2O and K_2O reacting with SiO_2 to form alkali silicates which imbibe water.

The literature on lithium silicates claims that such silicates are insoluble. One may visualize therefore that, as Na_2O and K_2O convert the reactive silica of an aggregate to soluble silicates, that these soluble silicates are in turn converted to an insoluble silicate by Li_2O. Calcium hydroxide dissolved in the liquid phase of the concrete would assist the Li_2O in converting sodium and potassium silicate to insoluble silicates. The formation of either an anhydrous or a hydrated metal silicate from silica in the space occupied by the particles of silica embedded in hardened cement paste would produce expansion unless the porosity of the particles of silica equaled or exceeded the increased volume of the silicate. However, since the insoluble silicate would not draw water into this space, the expansion caused by the insoluble silicate might be less than that produced by a soluble silicate.

If this is the mechanism by which Li_2O functions, then other salts might do the same. The requirements for the salt would be as follows:

1. It must form a relatively soluble hydroxide.

2. It must form a relatively insoluble silicate.

Barium salts meet these requirements and, accordingly, tests were made with certain barium salts. However, since $BaSO_4$ is extremely insoluble, it was necessary to use powdered clinker instead of cement in these tests because the sulfate in the normal cement would immediately precipitate the barium as barium sulfate.

A part of copyrighted JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, V. 31, No. 9, March 1960 (*Proceedings* V. 56). Separate prints of the entire Concrete Briefs section are available at 35 cents each. Address P. O. Box 4754, Redford Station, Detroit 19, Mich.

*Member American Concrete Institute, Director Research Laboratories, Universal Atlas Cement Division of U. S. Steel Corp., Gary, Ind.

EXPERIMENTAL

The following tests were made to determine whether or not barium ions would migrate through cement pastes. Two 1 x 1 x 11¼-in. specimens (A and B) of 1 part cement and 2.75 parts graded Ottawa sand were made and cured in the fog room for 24 hr. The cement used in Specimen A consisted of 97.9 parts clinker and 2.1 parts $BaCl_2$ and that used in Specimen B consisted of 95.8 parts clinker and 4.2 parts $BaCl_2$. The BaO, Na_2O, and K_2O contents in grams of each specimen were as follows:

Specimen	BaO	Na_2O	K_2O
A	1.10	0.82	0.40
B	2.89	0.80	0.39

The specimens, after the 24-hr curing period, were immersed in deionized water in polyethylene beakers. Periodically, the water was replaced with fresh water and the leach water was analyzed for BaO, Na_2O, and K_2O, with the results shown in Table 1. These results show that the BaO migrates with the alkalies through the cement pastes.

Tests for effect on expansion were made with 1 x 1 x 11¼-in. specimens made with 1 part cement to 2.25 parts graded Pyrex glass. The clinker used in these tests contained 0.90 percent Na_2O, 0.44 percent K_2O, and 0.09 percent SO_3. If a cement is to be made without gypsum, it is necessary to add a salt such as $CaCl_2$ to provide the required acceleration of the reactions for satisfactory strengths. Hence, the blank cements were powdered clinker plus 1.1, 2.2, and 3.3 percent $CaCl_2$. The cements containing barium salts were powdered clinker plus quantities of barium salts molecularly equivalent to the above amounts of $CaCl_2$. The specimens were stored for 24 hr in the fog room and then in accordance with ASTM C 227[2] at 73.4 ± 3 F. Tests were made with the chloride, hydroxide, acetate, nitrate, and chromate of barium. The chromate was used to study the effect of a relatively insoluble salt. Its solubility is given as 0.00034 g per 100 ml of water. Data for the expansions are given in Table 2.

The clinker was ground with sufficient gypsum to give a cement with approximately 2 percent SO_3. This plus blends of clinker with $BaCl_2$, $CaCl_2$, and mixtures of $BaCl_2$ + $CaCl_2$ were tested for compressive strength by ASTM C 109.[3] The results of these tests are given in Table 3.

TABLE 1—ANALYSIS OF LEACH WATER

Specimen A

Days of leaching	Oxides in leach water, g per specimen		
	BaO	Na_2O	K_2O
6	0.125	0.292	0.160
15	0.092	0.075	0.035
27	0.046	0.040	0.022
Total	0.263	0.407	0.217

Specimen B

Days of leaching	Oxides in leach water, g per specimen		
	BaO	Na_2O	K_2O
6	0.310	0.260	0.172
15	0.134	0.076	0.036
27	0.080	0.043	0.021
Total	0.524	0.379	0.229

RESULTS

The data in Table 2 indicate that soluble barium salts would be effective in reducing expansions caused by alkali-aggregate reaction. If this reaction is

$$SiO_2 + BaO + xH_2O = BaSiO_3 \cdot xH_2O$$

then 1.53 parts BaO would be required for each part of reactive SiO_2 in the aggregate. This is equivalent to 2.08, 2.61. 3.15, and 2.55 parts $BaCl_2$, $BaNO_3$, $Ba(OH)_2$, and $Ba(C_2H_3O_2)_2$, respectively.

The acetate and nitrate appear to be more effective than the chloride and hydroxide. It is expected that these salts would react with $3CaO \cdot Al_2O_3$ and $Ca(OH)_2$ to give salts such as $3CaO \cdot Al_2O_3 \cdot CaCl_2 \cdot xH_2O$, $3CaO \cdot Al_2O_3 \cdot CaNO_3 \cdot$

TABLE 2—EXPANSIONS OF 1 x 1 x 11¼-in. PYREX GLASS MORTAR SPECIMENS—AVERAGE OF THREE SPECIMENS

Salt used		Expansion at age indicated, percent						
Formula	Percent	1 week	2 week	3 week	4 week	8 week	12 week	6 month
$CaCl_2$	1.1	0.018	0.079	0.138	0.197	0.444	0.607	*
$CaCl_2$	2.2	0.013	0.058	0.123	0.173	0.352	0.478	*
$CaCl_2$	3.3	0.011	0.063	0.149	0.218	0.377	0.503	*
$BaCl_2$	2.1	0.008	0.016	0.031	0.044	0.113	0.187	*
$BaCl_2$	4.2	0.006	0.009	0.020	0.043	0.114	0.182	*
$BaCl_2$	6.3	0.009	0.011	0.017	0.018	0.096	0.183	*
$Ba(OH)_2$	2.71	0.002	0.014	0.041	0.060	0.103	0.110	0.119
$Ba(OH)_2$	5.42	0.008	0.013	0.026	0.041	0.083	0.100	0.103
$Ba(OH)_2$	8.13	0.006	0.010	0.022	0.034	0.073	0.091	0.107
$Ba(C_2H_3O_2)_2$	2.20	0.010	0.011	0.018	0.022	0.029	0.030	0.037
$Ba(C_2H_3O_2)_2$	4.39	0.011	0.015	0.018	0.018	0.022	0.025	0.033
$Ba(C_2H_3O_2)_2$	6.59	0.013	0.014	0.018	0.018	0.021	0.023	0.035
$BaNO_3$	2.25	0.008	0.014	0.031	0.045	0.079	0.090	0.102
$BaNO_3$	4.50	0.010	0.010	0.017	0.022	0.038	0.044	0.056
$BaNO_3$	6.74	0.010	0.010	0.016	0.018	0.024	0.027	0.035
$BaCrO_4$	2.18	0.017	0.073	0.129	0.171	0.215	0.218	0.227
$BaCrO_4$	6.53	0.013	0.070	0.116	0.153	0.185	0.187	0.194

*Tests discontinued at 12 weeks.

xH_2O, and $3CaO \cdot Al_2O_3 \cdot Ca(C_2H_3O_2)_2 \cdot xH_2O$, and $Ba(OH)_2$. Hence, one might expect all relatively soluble barium salts to behave about alike because they should be converted to $Ba(OH)_2$ within about the first 48 hr. It may be that the acetate and nitrate alumino compounds are more soluble than the chloride compound. Such differences in the solubilities of the compounds formed with $3CaO \cdot Al_2O_3$ might explain differences in the behaviors of the barium compounds.

TABLE 3—COMPRESSIVE STRENGTHS OF MORTAR CUBES

Specimen	Salt used		Compressive strength, psi, at day indicated		
	formula	percent	3	7	28
A	Gypsum	5.7	1660	2675	3640
B	$BaCl_2$	2.1	940	1365	2090
C	$BaCl_2$	4.2	1152	1665	2450
D	$BaCl_2$	6.3	1975	2120	2875
E	$BaCl_2$	8.4	1600	2160	2840
F	$CaCl_2$	3.3	2460	3290	4060
G	$CaCl_2$	4.9	2360	3260	3890
	$BaCl_2$, percent	$CaCl_2$, percent			
H	1.2	2.5	2058	2842	3570
I	2.4	2.0	1974	2642	3358
J	5.0	1.0	1589	2200	2883
K	—	3.0	2875	3633	4525

$BaCl_2$ does not appear to be equivalent to $CaSO_4$ and $CaCl_2$ in producing strengths. However, it appears that satisfactory strengths could be obtained by using mixtures of $BaCl_2$ and $CaCl_2$.

If blends of clinker plus barium salts are to be used instead of regular cements with reactive aggregates, it would be desirable to select clinkers with low SO_3 contents and clinkers that would give satisfactory setting times when used with these salts instead of gypsum.

REFERENCES

1. McCoy, W. J., and Caldwell, A. G., "New Approach to Inhibiting Alkali-Aggregate Reactions," ACI JOURNAL, V. 22, No. 9, May 1951 (*Proceedings* V. 47), pp. 693-708.

2. *ASTM Standards on Mineral Aggregates and Concrete*, American Society for Testing Materials, 1958.

3. *ASTM Standards on Cement*, American Society for Testing Materials, 1958.

Ultimate Strength Design of Rectangular Cross Sections Under Bending with Tensile Steel Only

By R. J. AMSTAD*

Ultimate strength design of cross sections is included in the appendix to ACI 318-56 which postulates limiting equations and conditions, the explanation of these being given in "Guide for Ultimate Strength Design of Reinforced Concrete" by Charles S. Whitney and Edward Cohen.† This article presents another method for preparing similar design charts.

NOTATION

A_s = tensile steel area
a = depth of rectangular stress block
b = width of rectangular beam or column or total width of T-beam flange
d = distance from extreme compressive fiber to centroid of tension force in tensile reinforcement; also, in a column with a circular core, the diameter of the circle passing through the centers of reinforcing bars
f_c' = 28-day concrete cylinder strength
f_y = yield point stress in steel, but not greater than 60,000 psi for design purposes
M_u = ultimate bending moment
p = A_s/bd

The diagram in Fig. 1 shows the arrangement of stresses and when computing characteristics of the section no cognizance of strains as such is made. We have therefore

$$\text{Force in concrete} = 0.85\, f_c' ab$$

$$\text{Force in steel} = f_y A_s = f_y pbd$$

For equilibrium these must be equal. Therefore,

$$f_y pbd = 0.85\, f_c' ab$$

$$pf_y/f_c' = 0.85\, a/d \qquad (1)$$

Eq. (A2) of ACI 318-56 limits pf_y/f_c' to 0.40, which is specifically to preclude the possibility of a sudden concrete compression failure.

Taking moments about the tensile steel we have

$$M_u = 0.85\, f_c' ab(d - a/2)$$

from Eq. (1) above $a = pf_y d/0.85 f_c'$; therefore

$$M_u = \frac{pf_y}{f_c'}\left(1 - \frac{pf_y}{1.7\, f_c'}\right) f_c' bd^2 \qquad (2)$$

$$\frac{M_u}{f_c' bd^2} = \frac{pf_y}{f_c'}\left(1 - \frac{pf_y}{1.7\, f_c'}\right) \qquad (3)$$

---

*London, England.
†ACI JOURNAL, V. 28, No. 5, Nov. 1956 (*Proceedings* V. 53), pp. 455-490.

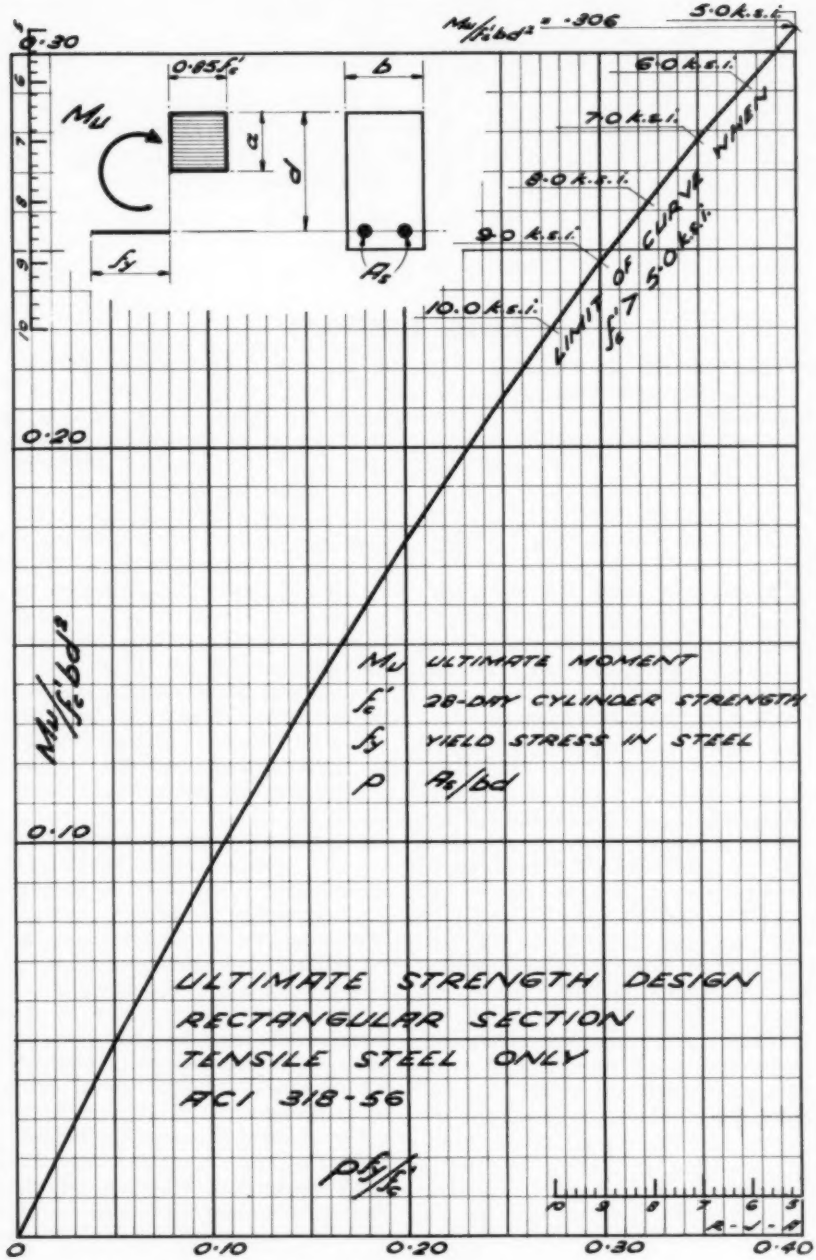


Fig. 1—Design chart for rectangular section

if $q = pf_y/f_c'$ we have from Eq. (2) $M_u = q(1 - 0.588q)\, f_c'\, bd^2$, which is Eq. (A1) of ACI 318-56.

By substituting values of pf_y/f_c' from 0 to 0.40 (the limit) we can obtain the graph in Fig. 1.

When f_c' exceeds 5.0 ksi pf_y/f_c' is reduced by 0.025 per 1.0 ksi. Again this is to preclude a compression failure due to the change in shape of the concrete compression block with increase in strength. It *tends* toward a triangular shape. Note that this is easily incorporated in the graph in a convenient way.

Load Factors

This interesting discussion developed between Prof. Eduardo Torroja, chairman of the ICBR committee that reported on "Load Factors" [ACI JOURNAL, V. 30 No. 5, 1958 (Proceedings V. 55) pp. 567-572], and Prof. Alfred Freudenthal and is here presented because of its general interest.
—EDITOR

By ALFRED FREUDENTHAL*

THE PUBLISHED ABSTRACT of the report of the International Council for Building Research is but another illustration of the deep-seated resistance of even the best engineering minds to the application of genuine probability concepts and rational statistical methods in structural analysis. The fatal fascination which the Normal or Gaussian distribution exerts on engineers and physical scientists alike and which has already been noted by Poincare (whose statement that mathematicians use this distribution because they believe it to be a physical reality, while scientists use it on the basis of their belief that it is mathematically well founded, can not be repeated as a warning frequently enough) is apparently matched only by the fascination of structural engineers with the concept of "load factors," erroneously believed to represent an advance over the concept of the "working" or permissible" stress. Neither of these two concepts, on which the report is mainly based, can withstand the test of a rational analysis of the problem of safety in relation to the probability of failure.

In the light of such an analysis the introduction of load factors only replaces the single conventional factor of safety implied in the permissible stress by two or more separate factors for dead load and for various types of service and accidental loads, each of which presumably reflects a range of independent statistical variation, but without provision for an adequate statistical summation of these variations. The expression for L_b on p. 570 of the November 1958 JOURNAL certainly bears no relation to statistical theory.

Whether several separate guesses are in themselves preferable to a single guess is debatable, especially when it is proposed to add the results of the separate guesses with the aid of an irrational procedure.

The safety factor $v = R/S$ defined as the ratio of structural resistance R and total applied load S, both of which are statistical variables, is itself a statistical variable, being the quotient of two

*Professor of Civil Engineering, Columbia University, New York, N.Y., and chairman of ASCE Committee on Safety Factors.

variables, with a distribution $p(v)$ uniquely defined by the distributions $p_1(R)$ and $p_2(S)$. The cumulative distribution $P(v) = \int_0^v p(v)dv$, which is the probability of occurrence of safety factors $\leq v$, at $P(v) = 1$ represents directly the probability of failure; this probability is thus simply related to the distributions of R and S and to their relative positions, determined by the ratio of the means $\overline{R}$ and $\overline{S}$, the modes $\widetilde{R}$ and $\widetilde{S}$, or the medians $\breve{R}$ and $\breve{S}$, considered as a specified "central" value of the safety factor: $v_0 = \overline{R}/\overline{S}$ or $\widetilde{R}/\widetilde{S}$ or $\breve{R}/\breve{S}$, around which the actual safety factors are statistically distributed. In this concept of the safety factor, which is directly and simply correlated with the probability of failure (or unserviceability), separate "load factors" are devoid of any meaning, since partial loads cannot be related to failure or unserviceability.

This lack of rationality of the load factor concept is an inexhaustible source for argument and questionable contentions concerning the particular combination of load factors to be selected out of the infinite number of possible combinations pertaining to a specific, yet unknown, probability of failure. Moreover, the proposed segregation of a "factor of safety" or "reduction factor" with respect to material strength from the various factors applied to loads is theoretically untenable. The statistical variation of a quotient is not obtained by separating the variation of the numerator from that of the denominator.

It appears that the proposed numerical values of the various load–and strength-reduction–factors are, in some rather vague manner, related to the assumption of Normal distributions of loads and of material properties. However, in the numerous series of observations of the variations of material properties reported by various authors in different countries Normal distributions are hardly ever encountered. The fitted distributions are usually significantly skew. While observations of load intensities, particularly in buildings, are rather scarce, it is unlikely that they can be fitted by a Normal distribution, as this would imply equal probabilities of downward and upward fluctuations of the same range, while it is more reasonable to expect, on the basis of all relevant experience, that the range of downward fluctuations from the most probable (modal) value is much narrower (since limited by zero) than the range of upward fluctuations. Observations of motor vehicle weights, or wind and gust loads, of flood levels on rivers producing the load on dams, etc., consistently show this type of skewness. It is therefore hardly justified to place too much reliance on probability values associated with plus or minus one standard deviation in a Normal distribution. The differences in those probabilities due to even moderate skewness are quite significant.

There can be no doubt that the International Council must be well aware of all the points raised above. Professor Torroja's own important contribution to the statistical theory of safety, particularly the monograph written under his direction by Dr. Paez, "Calculation of Factor of Safety in Constructional Work," clearly established the rational correlation of the single safety factor with the probability of failure, using physically relevant skew distribution functions. It is more difficult to understand why the International Council has adopted a "practical" point of view when it appears to be in direct opposition to the rational theory of safety developed by its chairman, a theory that could have provided a suitable basis for a real improvement of the conventional approach to structural safety.

In this writer's view, the proposed procedure does not represent an improvement over the conventional approach based on permissible stresses.

The advantage of a design based on load limits rather than on stresses, which permits the consideration of the actual failure mechanism of the whole structure instead of the resistance of a critical section, is completely destroyed by the introduction of more or less arbitrary separate load factors unrelated to the probability of failure.

Only a single safety factor in which the uncertainties of loading and of material resistance are combined, and which is associated with a *computable* probability of failure—serving primarily as a yardstick for comparison of the safety of different designs as well as for the achievement of uniform safety in the various parts of the same structure—can provide a rational solution of the problem of structural safety.

By EDUARDO TORROJA*

The objections made by Professor Freudenthal may be divided into three headings, or arguments, each quite distinct from the others:

(a) Disagreement with Gauss law.

(b) Disapproval of a separate study, or separate treatment, of the variables R and S, which define the factor of safety $v = R/S$.

(c) Disagreement that the failing load S can be correctly made up as the sum of the partial loads, S_1, S_2, . . . due to dead weight, overloads, wind, etc.

Item a

As Professor Freudenthal said, there is no special argument in favor of a perfect symmetry for the distribution of the statistical frequencies defining a given physical phenomenon. In the theoretical investigations on which the report of the committee was based, there were few distributions that could be regarded as normal. As mentioned in the previous discussions,† the various compositions of the variables were achieved by methods which made it possible to introduce experimental laws, outlined by a series of points, i.e., there was no need to make them correspond to any given function.

By means of these laws, obtained directly from the statistical data, certain results were inferred, from which the probability law, giving the probability of failure, $p(v)$, in terms of the factor of safety, $v = R/S$, was finally worked out.

Up to here there is full agreement with Professor Freudenthal.

The divergencies arise when, after completing the basic theoretical investigation, a simple way is sought to apply the results to the problems which arise in practice.

It cannot be supposed that the engineer shall begin his project by calculating deviation laws for concretes which will have to be made after the project is approved and the contract adjudicated. Hence there is a need to assume a standard probability law, and to define simple requirements whereby concrete, made at the working site, can be accepted or rejected in each particular case.

Item b

The theoretical work which was the basis for these specifications was carried out in the manner mentioned by Professor Freudenthal; namely, by calculating the function $P(v)$ as an expression of the probability that the ratio $v = R/S$ shall surpass a given value v, where R and S are two probability functions.

A difficulty arises on applying this to practical cases. Whereas in the case of beams their strength depends basically on the possible variations of the mechanical strength properties of the reinforcement, in the case of columns

*Member American Concrete Institute, Director and Professor, Instituto Técnico de la Construccion y del Cemento, Costillares, Madrid, Spain.
†ACI JOURNAL, V. 30, No. 12, June 1959 (*Proceedings* V. 55) pp. 1387-1401.

and arches it is the properties of the concrete that are the primary determinant of their strength.

Hence, the factor of safety varies with the type of structural part that is being considered, since the variability in the properties of steel is less than in concrete. As there is a continuous range of variation between a column and a lightly reinforced beam, it follows that the factor of safety should vary with the percentage of steel. The greater this is, the smaller the influence of the concrete on the final strength of the structural part.

To overcome this difficulty, separate factors of safety are allocated to the concrete and to the reinforcement.

Certain coefficients were obtained as a result of analyzing 600 practical instances. The criterion and formulas proposed by the committee are justified by the fact that, in an immediate and automatic manner, they reproduce the results obtained after a rigorous investigation of the various particular cases considered.

It will be noticed that the divergencies with Professor Freudenthal are due less to differences in criterion than to the manner of presenting the results so as to attain a greater simplicity in their practical application.

Item C

The loads and overloads acting on a structure consist of a number of actions, of diverse intensity and probable incidence.

Strictly, to each combination of loads and overloads, there corresponds a particular probability law. Consequently, the factor of safety varies depending on the loading hypotheses and on the number of loads which are assumed to act simultaneously. The same factor of safety cannot be presumed for the loading case corresponding to dead weight and a train overload, as for the case involving the simultaneous action of a hurricane and an earthquake.

Each combination of overloads, and their corresponding probability laws, will require a detailed investigation, to express the factors of safety as functions of the pertinent distribution laws. The designer will have to consider each of these hypotheses, without neglecting any of them, as he ignores *a priori* which is the most unfavorable combination, taking into account that the margins of safety are different for each combination.

Summary

Summarizing, the objections raised by Professor Freudenthal are valid; the practical method which has been proposed is not perfect. Perhaps the final expressions give the impression of being more simple and inaccurate than is actually the case, taking into account the statistical investigation and the mathematical work which has been previously done to understand the problem more completely, and infer the most suitable results. To substitute for all this prior analysis some simple formulas implies that only an approxi-

The Problems and Practices section (which appears in Concrete Briefs section as space allows) is an open forum on everyday topics. JOURNAL readers are invited to contribute their solutions to problems that occur in the field or office — whether common or unusual.

Perhaps your solution is a better way of handling some everyday problem that others are looking for. Give your fellow ACI members the benefit of your experience on these problems.

Items appearing in this section can vary from 100 to 1000 words. It is an ideal place for those practical items generally considered too short to be submitted for publication, but containing material of potential importance to a great many.

mate solution is obtained, but in our view it is closer to the actual facts than the methods currently being applied in accordance with the various national specifications.

The factor $(1 + \sigma)$ would correspond exactly to a Gaussian type distribution. This is not true in many cases, but it is better than to adopt a fixed value, independent of the deviation of the variable (quality of the material or type of overload).

Furthermore, the factors c, which are to be multiplied by the brackets, may correct the discrepancies.

The manner of obtaining the coefficient $v = R/S$ would also be liable to criticism by a probabilities expert, but it is acceptable as a first approximation, for the sake of simplicity. The same applies to the manner of adding the characteristic overloads.

When, as a result of his investigations and his specialized knowledge, it becomes possible for Professor Freudenthal to present his own method and practical formulas, there will be full opportunity to study and evaluate these, and no doubt also to praise them. But in the meantime the Comite Europeen du Beton will continue to recommend their own system with the understanding that it is a provisional one until a better one is found.

CONTRIBUTIONS TO THE ACI JOURNAL

Technical pages of the ACI JOURNAL offer a medium for reporting what is new and interesting in concrete research, design, construction, maintenance, or manufacturing. ACI members and JOURNAL readers are urged to share their knowledge and experience by submitting papers and reports for publication in the ACI JOURNAL.

The Technical Activities Committee selects the papers, committee reports, discussions, and other contributions for JOURNAL publication. A volunteer corps of experts in various segments of the field assists in technical appraisal of the manuscripts. Technically speaking, acceptable contributions present original material for improvement of design, manufacturing, or construction; confirm, revise, or upset established ideas or practices; or review, digest, or arrange accumulated experience for more ready use.

Contributors should furnish glossy prints or inked tracings of illustrations along with manuscripts submitted in triplicate for publication. Details of the form and physical arrangement of contributions are given in the 1959 **ACI Directory** p. 15.

Secretary, Technical Activities Committee

AMERICAN CONCRETE INSTITUTE

P.O. BOX 4754, REDFORD STATION, DETROIT 19, MICHIGAN

CURRENT REVIEWS

of Significant Contributions in Foreign and Domestic Publications

Bridges

Progress report on inhibiting the corrosion of steel in a reinforced concrete bridge

R. F. Stratfull, *Corrosion*, V. 15, No. 6, June 1959, pp. 65-68

Highway Research Abstracts Sept. 1958

Experimental techniques used to inhibit the corrosion of steel in a reinforced concrete bridge are described. Control methods used include application of cathodic protection, addition of capillary water to the concrete to produce oxygen starvation, and use of paints to produce moisture equilization within the concrete. Role of absorbed moisture and sea salts in promoting corrosion is discussed briefly. Because several tests still remain to be made and evaluated, data are presented as a progress report, not as conclusions for design criteria.

Thoughts on the waterway areas of small highway bridges (Considerations sur les debouches des petits ouvrages sous routes)

A. Delorme, *Annales des Ponts et Chausses* (Paris), V. 129, No. 2, Mar.-Apr. 1959, pp. 141-167

Reviewed by Aron L. Mirsky

Author suggests defining permissible frequency of submersion in terms of the characteristics of the road and the possible damage, and then presents a statistical approach, using Gumbel's "Law of the Extreme Value," for finding flow Q of the maximum flood to be expected on a given river over a period of T years. A practical example is included.

Contractor's consultant redesigns bridge to cut costs

Construction Equipment, V. 20, No. 6, Dec. 1959, pp. 34-38

When this contractor won the bid for a 1040-ft prestressed bridge they asked a consultant to find a better and more economical way to do the job. The original design called for nine 100-ft and two 70-ft precast, prestressed spans. The 100-ft precast girders would have required moving them over rough terrain. The engineer's redesign (approved by the owner) to a cast-in-place prestressed superstructure saved equipment and manpower. For the 11-span bridge, spans were completed one at a time in 12-day cycles. Article gives details on mix, concrete placing, use of retarders and revibration, use of lightweight falsework, and prestressing.

St. James's Park bridge

Francis Walley, *Proceedings*, Institution of Civil Engineers (London), V. 12, Session 1958-59, Feb. 1959, pp. 217-222

Reviewed by Aron L. Mirsky

Brief extract from author's paper, describing a continuous three-span bridge of prestressed concrete with an over-all width of 13 ft 6 in., two ribs each 2 ft 6 in. wide, and minimum over-all depths of 14 in. at the center and 10 in. at the abutments. To achieve

---

A part of copyrighted Journal of the American Concrete Institute, V. 31, No. 9, Mar. 1960, *Proceedings* V. 56. Address P.O. Box 4754, Redford Station, Detroit 19, Mich. Where the English title only is given in a review, the book or article reviewed is in English. If it is followed by a foreign title the work reviewed is in that language. In those cases where the foreign title cannot conveniently be set in type or is not available, the language of the original article is indicated in parentheses following the English title. Copies of articles or books reviewed are not available through ACI. Available addresses of publishers are listed in the June "Current Reviews" each year. In most cases ACI can furnish addresses of publications added later.

For those members who cut apart this section for pasting on cards for card indexes, a limited number of complimentary reprints of the "Current Reviews" section are available from ACI headquarters on request.

this slenderness, design and construction were based on a structure simply supported on the two piers; on completion of stressing the ends of the bridge were dropped onto the abutments and one pier was fixed, the structure thus being made continuous. Natural frequency of structure was found of especial importance (a simplified method of calculation is given in an appendix); the fixing of one pier resulted in an acceptable value. To test the bridge, 300 guardsmen were marched across in step at various marching rates.

Construction

Ochsenkopf television tower

The Engineer (London), V. 207, No. 5392, May 29, 1959, pp. 863-864; No. 5393, June 5, 1959, p. 901

Reviewed by ARON L. MIRSKY

Another interesting, free-standing, concrete television tower, this one in northeastern Bavaria. The tower, 163 m high and surmounted by a 13.5 m mast, is designed to deflect 1.08 m in a 167 km per hr wind. The reinforced concrete design is stated to meet all technical requirements in addition to its convenience (staff and equipment are housed inside the tower, feeder cables are kept short, cables and connections are accessible at all times, aerials and running lights are easily accessible), good appearance (the outside diameter decreases in a parabolic sweep from 19.1 m at ground level to 4.5 m at a height of 66.7 m; above this the diameter is constant), and low maintenance costs. The total cost of the station is claimed to be approximately same as a steel mast.

Construction of 132 kv switch house at Belvedere, Kent

I. GLOVER and P. P. FOWLER, *The Engineer* (London), V. 207, No. 5382, Mar. 20, 1959, pp. 450-454

Reviewed by ARON L. MIRSKY

Reinforced concrete structure, with frame of precast elements clad with corrugated aluminum sheet lined with insulating material, was selected on basis of minimum over-all cost (with special emphasis on maintenance cost) consistent with functional efficiency and reasonably pleasing appearance. Site is a flat, low-lying marshy area by the River Thames, with air pollution from adjacent industries and possible flooding as complicating factors. On-site quality control of the concrete was used with satisfactory results.

Deas Island Tunnel

D. A. YOUNG, PER HALL, T. BROENDUM-NIELSEN, H. R. KIVISILD, A. T. JEFFREY, and O. H. BENTZEN, *The Engineering Journal* (Montreal), V. 42, No. 4, Apr. 1959, pp. 58-71

Reviewed by ARON L. MIRSKY

Tunnel, a four-lane motor vehicle facility under the Fraser River near Vancouver, involved some interesting structural problems, including earthquake loading. Paper covers all aspects; general layout, structural design, hydraulic design, technical installations, and construction procedures. [Also see *Engineering News-Record*, May 22, 1958, pp. 34-36, 39-40; and *Civil Engineering*, July 1958, pp. 34 ff.]

Chimney 350 ft high at a cement works

JOHN FABER, *Concrete and Constructional Engineering* (London), V. 54, No. 11, Nov. 1959, pp. 363-369

This reinforced concrete chimney, about 350 ft high, is of circular cross section and tapers uniformly from an external diameter of 26 ft 4 in. at the foundation to 13 ft at the top.

The temperature of the flue gas is normally 485F but a maximum temperature of 800 F is allowed for in the design. The chimney is lined with engineering bricks jointed with corrosion resistant mortar, carried on continuous reinforced concrete corbels projecting from the concrete shaft at intervals of 40 ft in height of the chimney. Each height of the lining is tapered to protect the corbel carrying the next height of bricks above but is free to expand.

Ports are provided in the shaft and through the corbels to facilitate ventilation.

Foundations to minimize heavy vibrations

Engineering (London), V. 187, No. 4849, Feb. 13, 1959, pp. 212-215
Reviewed by ARON L. MIRSKY

Site of aircraft plant is flat and sandy, underlain by a peat stratum extending for many miles and under this there is a soft, deep stratum of unstable silt. The foundations for the stamps were open-well type (topless caissons), of reinforced concrete with Lee-McCall stressing bars and jacks used to control distortion. The press foundation is also the caisson type, but on driven bearing piles.

Construction Techniques

Modern classification methods applied to fine aggregates

C. E. GOLSON, *Pit and Quarry*, V. 52: No. 2, Aug. 1959, pp. 95-99, 114, 118; No. 3, Sept. 1959, pp. 89-96

Well-illustrated article on the theory and application to fine aggregate improvement of various types of classification equipment originally developed for mineral dressing. Equipment discussed includes velocity classification devices, accelerated settling equipment, and hindered settling devices.

Slab-on-ground construction

Concrete Construction, V. 4, No. 11, Nov. 1959, pp. 10, 12, 14, 16, 18, 20-21

Careful attention to some basic principles of all good concrete construction can head off possible trouble when residential floors are built directly on the ground. This article calls attention to some of the aspects of this type of construction which are most likely to cause trouble and suggests some precautions which the builder can observe to assure better results. Topics covered include grading, slab bed, vapor barriers, slab insulation, reinforcement, concreting, and curing.

Use of gamma radiography to detect faults in grouting

J. A. FORRESTER, *Magazine of Concrete Research* (London), V. 11, No. 32, July 1959, pp. 93-96
AUTHOR'S SUMMARY

Describes the use of gamma radiography to detect defective grouting. The technique was used to examine a prestressed beam which had been badly grouted intentionally; faults were detected, and their presence was confirmed by breaking open the specimen.

Vibration-pressure method of soil preparation for concrete pile driving

JOHN GRINDROD, *Indian Concrete Journal* (Bombay), V. 33, No. 11, Nov. 1959, pp. 389-390

Discusses a new vibration-pressure method of compaction known as *Das Rutteldruckverfahren* which had been developed by a German firm. This method has been found advantageous when used in connection with driving of concrete piles or anchor blocks.

The German compacting machine is introduced into the soil down to the desired depth and from this level upwards compacts a spherical volume of soil about 5-ft radius. By a pattern of insertions side by side it is thus possible uniformly to compact soil masses of any desired dimension and depth. The distance from one insertion to another being governed by the degree of load bearing capacity required and by the structure of the soil.

By this method the soil is not only exposed to the vertical and horizontal vibrations of the machine but the compacting process is enhanced by forcing water through the tubular shaft for emission through slots near the vibrator, which is operated electrically. Compaction takes place as the machine is gradually withdrawn from the depth to which it has been sunk, leaving a cylindrically shaped compact mass which is capable of taking much shorter concrete piles than would otherwise have been required. The article describes an application of this method for an artificial fertilizer depot in Holland.

The pile length was reduced from about 42 ft to 16 ft thus permitting a considerable saving.

External vibration of concrete

J. KOLEK, *Civil Engineering and Public Works Review* (London), V. 54, No. 633, Mar. 1959, pp. 321-325

AUTHOR'S SUMMARY

A review of the principles of compaction of concrete by vibration. The influence of acceleration, amplitude, and frequency is discussed and a generalized theory of compaction is suggested. A distinction is made between two aims in using vibrators for concrete purposes and an experiment is described to find the influence on these aims of the frequency of vibration. Practical recommendations are quoted for external vibration including guiding points for the estimation of the type and the number of vibrators needed. Results of a survey of external vibrators are also included.

Wanted! New data and standards on masonry anchoring devices

F. A. WERSTEIN, *Fasteners*, V. 14, No. 2-3, Summer 1959, pp. 9-13

After describing various general types of fasteners used in masonry and concrete, author cites need for development of reliable test data and standards for the guidance of engineers and architects. Suggests close liaison between anchor manufacturers, architects, engineers, and manufacturers of building materials to determine technical information needed and what system of standards will best suit the needs of designers of structures.

Unusual forming demanded by school design

Contractors and Engineers, V. 57, No. 1, Jan. 1960, pp. 10-14

This new concept in school design has the academic wings extending out from a circular core like the spokes in a wheel. Arch and shell construction was used for the roof of the swimming pool wing.

Four cast-in-place arches support a 3½-in. concrete deck. The arches extend outside the building, spanning 157 ft at their base. The entire roof structure was formed as a unit and concrete was placed monolithically. In forming the high basement walls of the 210-ft diameter core building, steel-backed plywood panels were used. The core building was three stories and the academic wings two stories high. The two-story wings were framed with concrete columns supporting pan-type floors. Formwork and centering are described in some detail.

Use of membranes for curing of concrete

P. J. JAGUS and K. L. SETHI, *Road Research Papers*, Central Road Research Institute (Delhi), No. 29, Dec. 1958, 23 pp.

This study deals with the efficacy of using different membranes, both liquid as well as solid, for curing concrete. The various membranes tried were plastic film, waterproof packing papers, bitumen cutback, bitumen-emulsion, bitumen primer, and wax emulsion. The results indicate that the solid membranes are generally superior to the liquid membranes. Out of the solid memberanes, plastic film gave the best results and thus deserves field trials. Use of these types of membranes in arid regions of the country, where there is shortage of water, will effect economy in the cost of concrete curing.

Pier-cap repair with epoxy resin

Contractors and Engineers, V. 57, No. 1, Jan. 1960, pp. 98-99

The Texas State Highway Department used an epoxy resin to repair some badly spalled pier caps on a seven year old bridge.

The damage on the bridge generally occurred on the cast-in-place pier caps that supported the two fixed ends of the simple spans (seventeen 30-ft spans). On these piers the cap was joined to the two pan-type slabs by two rows of 3/4-in. dowels. Normally the spalling occurred on only one side of

the cap. Caps under the expansion joints suffered no damage.

The adhesive used was a combination of epoxy and nylon resins. The repair procedure was as follows: To allow for the movement of the deck slab, the dowel bars connecting the cap to the deck were exposed and cut. Surface of the spalled area was cleaned and painted with the epoxy resin. Pneumatic mortar was then sprayed onto the "painted" surface of the spalled area and built up in several layers.

Tooled finishes for concrete

Concrete Construction, V. 4, No. 6, June 1959, pp. 12-14

Brief instructions on bush hammering and point tooling hardened concrete. Suggestions are made for forming, concrete mixtures, and proper time for tooling.

Design

Calculation of arbitrarily loaded rectangular plates by the method of influence surfaces (in Serbian)

S. Turk, *Nase Gradevinarstvo* (Belgrade), V. 13, No. 5, May 1958, pp. 97-107
Reviewed by J. J. Polivka

Author's method assumes extension of the actual plate beyond its boundary by a "fictitious surface" so that a larger, but statically simpler "ideal plate" is obtained. This fictitious surface is subjected to a fictitious loading so chosen that the results, which takes into account all boundary conditions, are valid for the actual plate. In determining the shape of the ideal plate three procedures are considered: ideal plates with finite dimensions; ideal plates in the form of infinite strips; and of an infinite plate. The fictitious loading is determined according to boundary conditions of contact edges, viz., edges at which the actual plate and the fictitious surface make contact. This method can also be used in a simple way for continuous and triangular plates.

Ultimate-load design cuts cost of building

Engineering News-Record, V. 163, No. 13, Sept. 24, 1959, pp. 38-39

Briefly reviews the utimate load design for a community hospital. This design permitted minimum beam depth and reduced the need for compression steel. Design also employed the use of lightweight concrete for fire rating purposes.

Examples of the design of reinforced concrete buildings

Charles E. Reynolds, Concrete Publications, Ltd., London, 2nd Edition, 1959, 265 pp., $3

This edition is revised to conform to the recommendations of the current British standard codes of practice for reinforced concrete buildings, particularly Code No. 114 (1957) and other subsidiary codes.

In part one, the recommendations of these codes and other supplementary data relating to the design of buildings are considered in the same sequence as in design calculations, namely; loads, bending moments, shearing forces, stresses, resistance to bending, resistance to shearing force, and bond. Structural parts are then considered in the order in which design proceeds, namely: slabs, beams, columns, load bearing walls, stairs, basements, and foundations.

Part two then illustrates the methods of designing by applying the recommendations of the code to the design of the principal parts of a reinforced concrete building. Included are 21 calculation sheets and 17 pages of drawings. Alternative designs are given for some structural parts of the buildings, demonstrating different types of construction.

Torsion in reinforced concrete sections

S. Sarkar, *Indian Concrete Journal* (Bombay), V. 33, No. 11, Nov. 1959, pp. 391-393

In the majority of reinforced concrete frame structures, there is some torsional moment in beams but since

it is comparatively small, it is assumed to be resisted by the concrete alone. Generally a simple two-dimensional analysis is considered sufficient for practical purposes. However, in special structures, such as balcony girders and beams curved in plan in which the torsional stresses are high the provision for suitable reinforcement becomes necessary. This paper gives a brief treatment of the problem for reinforced concrete beams of uniform rectangular section.

For rectangular frames the torsional moments are calculated by the extension of the moment distribution method to three dimensions. The author then compares the values of stiffness in torsion obtained by methods of Anderson and of Timoshenko and Goodier. He also makes a comparison of torsional shear stress obtained from expressions recommended by various authorities.

Although a continuous spiral following the lines of principal tension would be the most satisfactory reinforcement, this is not practical due to difficulties of fabrication and construction. The author recommends the use of a method proposed by Anderson which is conservative and errs on the safe side. It is particularly suitable for torsional reinforcement for beams curved in plan, where placing a rectangular spiral along a curve presents additional difficulty.

Ultimate strength design of reinforced concrete members

S. K. Samaddar and K. S. Rakshit, *Indian Concrete Journal* (Bombay), V. 33, No. 11, Nov. 1959, pp. 379-383

Reviews various methods of analysis and design of reinforced concrete members by the use of ultimate strength. It gives the design of rectangular beams by actual stress distribution method, Whitney's stress block method, and Jensen's stress distribution. Authors then apply the same methods to the design of T-beams, doubly reinforced beams, and columns. Briefly discusses load factors.

Plastic buckling of the circular-cylindrical shell (Plastische Knickung der Kreiszylinderschale)

H. Neuber and G. Landgraf, *Der Bauingenieur* (Berlin), V. 34, No. 2, Feb. 1959, pp. 44-48
Reviewed by Aron L. Mirsky

Using as a point of departure W. Flügge's results for purely elastic buckling* (rather than W. Kaufmann's, which, although for plastic buckling, involve many simplifying assumptions), authors investigate buckling of cylindrical shells of reinforced concrete for two cases of loading (uniform radial external pressure; uniform axial pressure) and two assumed types of plasticity (anisotropic: different moduli in the radial and axial directions). Stability criteria for the four cases are developed, and numerical results (obtained by iteration methods) presented in the form of curves, one for each of the two concrete strengths assumed.

*_Statik und Dynamik der Schalen_, Springer, Berlin, 2nd Edition, 1957.

Theory of live load in buildings (in Spanish)

Emilio Rosenblueth, *Revista Ingenieria* (Mexico), V. 29, No. 4, Oct. 1959, pp. 51-72
Author's Summary

From the assumption that maximum live load in a given element of area is independent of that on floor $w = w_o(1 + cf/\sqrt{A})$ where w is the design unit live load associated with the loaded area A and with a given generalized stress; c is a dimensionless parameter depending on the shape of the influence surface for the generalized stress in question; w_o (in psf) depends only on the intended use of the floor, and f (in ft) depends on intended use and on the allowable probability of failure. In particular, when the generalized stress considered is equal to the total load on A the influence surface has constant ordinate and $c = 1$. This result coincides with that due to J. F. Baker *et. al.*, (*The Steel Skeleton*, V. 2). Elastic and plastic analysis of beams with various end conditions, colums, and two-way slabs shows that with an appropriate definition of

loaded area, c can be taken as 1.2 for most practical cases without undue error. Theory is satisfactorily verified by observed maximum loads (not due to people) in loaded areas not smaller than 10 sq ft for office buildings. Paper includes considerations on other stochastic variables pertinent in structural design.

Computation of conical shells loaded by the wind (in Polish)

JOZEF LEDWON, *Arichwum Inzynierii Lodowej* (Warsaw), V. 5, No. 3, 1959, pp. 301-320
Reviewed by STEVEN GALEZEWSKI

Discusses a vertical, open, conical shell subjected to a wind load that varies linearly along the axis. The method presented deviates from the classical theory of shells. A numerical example, shown in conclusion, assumes a 200 ft high cooling tower designed as a conical shell.

Design criteria for residential slabs-on-ground—Interim report

Building Research Advisory Board, National Academy of Sciences, National Research Council, *Publication* No. 657, 1959, 74 pp., $2

Presents tentative recommendations on design of slabs-on-ground based on soil and climatic conditions. Because of these and other variables the committee has devised recommendations on four types to provide range of selections. The types of slabs are unreinforced floating slabs, reinforced floating slabs, stiffened slabs, and structural slabs. Selection of type of slab is based on soil type at the building site, thickness and distribution of soil types, and consistency of clay soils and density of granular soils. Detailed procedures are then set down for the selected type of slab.

Recognizing the need for further research in this field, recommendations are made for investigation of granular mats, soil-moisture relationship, swelling properties of clay soils, soil stabilization, and identification of problem soil areas. Further studies are suggested of cracking of slabs, effect of partition loads on floating slabs, maximum deformation of unreinforced slabs, rigidity of stiffened slabs, and controlled design and construction.

Analytical stress determination for tunnel cross sections (Analytische Spannungsermittlung bei Tunnelquerschnitten

G. ERAS, *Der Bauingenieur* (Berlin), V. 34, No. 2, Feb. 1959, pp. 49-53
Reviewed by ARON L. MIRSKY

Analytical expressions are obtained by use of complex stress functions and conformed mapping methods. Power series representations used are shown to converge rapidly. Numerical results for a tunnel of rectangular section with arched roof are shown to be in good agreement with those previously obtained by Hiltscher, using photoelasticity [*Der Bauingenieur*, V. 32, No. 8, Aug. 1957, pp. 288-291; "Current Reviews", ACI JOURNAL, V. 30, No. 6, Dec. 1958 (*Proceedings* V. 55), p. 742].

Materials

Method for following the hydration reaction in portland cement paste

J. H. TAPLIN, *Australian Journal of Applied Science* (Melbourne), V. 10, No. 3, Sept. 1959, pp. 329-345
AUTHOR'S SUMMARY

A simple method is described for determining the amount of hydration products in specimens of fresh or hardened cement paste. Data are presented showing the course of the hydration reaction at 25 C for curing periods of 1 hr to 1 year for paste specimens with water-cement ratios of 0.157 to 0.80. From the limitation of the reaction at low water-cement ratios, the hydration products of this cement are estimated to occupy 2.2 times the volume of the clinker from which they were formed.

Three suggestions are made concerning the hydration products which form outside the original boundaries of the clinker particles: (1) the material has been transported there by diffusion through the pores in the hydration pro-

ducts; (2) the pore spaces in the gel of hydration products are too small for further nuclei of these products to form; (3) once these hydration products have formed, they are not mechanically disturbed by further hydration.

New classifier cuts labor, shipping costs

KNEELAND A. GODFREY, JR., *Rock Products*, V. 62, No. 9, Sept. 1959, pp. 125-130

A rising-current classifier, a familiar tool in the coal industry, was successful in removing coal particles and sticks from river gravel. Travel time of the dredge in searching suitable deposits was materially reduced, as were manpower and handling costs.

Investigation into the manufacture of high-strength concrete in a tropical climate

TOM RIDLEY, *Proceedings*, Institution of Civil Engineers (London), V. 13, (Session 1958-59), May 1959, pp. 23-34
Reviewed by ARON L. MIRSKY

Specifications for concrete for Iddo Overpass, Lagos, Nigeria, called for high strengths (prestressed concrete, 4500 and 7000; reinforced concrete, 3000 and 4500 psi for 6-in. cubes, at 7 and 28 days, respectively). Tests were accordingly carried out to determine mixes required to produce these strengths, in view of the high temperatures and high humidities prevalent in Lagos. It was found that lower water-cement ratios were required to overcome strength reductions due to the climate, thus necessitating an increased cement content to obtain adequate workability, but that the addition of 2 percent flaked calcium chloride gave a 25 percent improvement in strength plus adequate workability. Results have been good.

Nature and properties of engineering materials

ZBIGNIEW, D. JASTRZEBSKI, John Wiley & Sons, Inc., New York, 1959, 571 pp. $11

The purpose of this book is to emphasize the basic principles necessary for an understanding of the fundamental nature and properties of engineering materials and to make clear the significance of these principles in engineering practice. The objective has been to present a unifed treatment of a variety of materials, stressing the fundamentals which provide a common basis for explaining the behavior of the varied materials. Commencing with the structure of matter, and developing the information through colloids, phase transformations, and mechanical properties, the latter chapters deal with particular types of materials and properties. The major characteristics of metallic and ceramic materials and the principles involved in their production and manufacturing processes are discussed. The electrical and magnetic properties are considered again from the fundamental solid state approach while the thermal properties of materials are explained from the fundamental approach and illustrated by a number of important applications.

There is an extensive treatment of corrosion and its prevention, including the mechanisms of corrosion in various forms, which are explained by a reference to recent experimental evidence and theoretical developments. Similarly, the phenomena of friction, wear, and lubrication are explained from the point of view of surface physics and surface chemistry as well as the present engineering practice. One chapter deals with cementing materials and concrete

Note

Copies of books and articles reviewed are not available from ACI. Available addresses of publishers are listed in the June "Current Reviews" each year. In some cases ACI can furnish addresses of publications added later.

by explaining the mechanism of the physical, chemical processes that take place during or after their application. Although protective materials are closely related to the subject of corrosion, they are treated separately because of the wide scope in increasing importance of protective coatings in industrial applications.

The author includes information which until now has been available only in specialized higher level reference works. Many concepts considered to have been the domain of graduate and specialized courses are presented in a manner which should provide the reader with a basic knowledge necessary for intelligent selection and use of materials for specific engineering applications.

Pavements

Airfield pavement

Bureau of Yards and Docks, Department of the Navy, Revised Feb. 1959, 129 pp., $2.50 (Order PB 151617 from Office of Technical Services, U.S. Department of Commerce)

Practical and comprehensive engineering guide covering design and principles of construction most closely related to the use of concrete bituminous surfaced pavements and the evaluation and reinforcement of existing pavements. Among the topics covered are types of paving and their components; design criteria, principles, and procedures; subgrade preparation and drainage; subbases; surfaces; joints; and steel reinforcement. Information on the renovation of existing pavements includes all aspects from gathering topographical and soil boring data to actual paving operations. Recent revisions reflect the more stringent pavement requirements caused by the effects of heat from jet exhausts, the increased use of high pressure tires, and other aircraft advancements. In addition to numerous tables and illustrations, examples of applying the information to specific situations are presented.

Pavement profile surveys to correlate Michigan design practice with service behavior

William S. Housel and Olaf L. Stokstad, *Proceedings*, Highway Research Board, V. 38, 1959, pp. 149-182 (including discussion)
Authors' Summary

The paper first presents the correlation of Michigan pavement design with service behavior as developed from pavement performance surveys. Such surveys, initiated in 1925, serve as a primary basis of pavement design and emphasize soil conditions, drainage, moisture susceptibility, frost action, and climatic environment as controlling factors in pavement design. Methods devised in recent years for more precise evaluation of pavement performance are described. The significance of structural continuity and riding quality are discussed as integrated measures of pavement performance. A continuity ratio based on the cracking pattern of concrete pavements and a roughness index taken from accurately recorded pavement profiles are analyzed as quantitative measures of pavement performance. A truck-mounted pavement profilometer used in these surveys is described. Typical examples are presented from some 1500 miles of pavement profiles obtained in 1958 to show the relation between design practice and pavement performance and to bring out the promising possibilities of measuring pavement behavior under actual service conditions.

Investigation of a concrete pavement failure

Bh. Subbaraju and Y. C. Gokhale, *Road Research Papers*, Central Road Research Institute (Delhi), No. 22, Dec. 1958. 32 pp.

Describes an investigation carried out for determining the probable reasons for an early development of cracking of slabs of a cement concrete pavement in Mysore State, India. The probable cause of failure was attributed to the excessive differential swelling and shrinkage properties of the particular subgrade soil. Utilizing existing knowledge, an attempt has been made

to evaluate induced stresses based on theoretical considerations and also to estimate the probable crack expectancy period based on flexural strength values obtained from beams cut out from the road slabs. Some remedial and precautionary methods have been suggested, both for already laid concrete pavements as well as for new concrete pavement construction on highly expansive soil subgrades.

Precast Concrete

Here's a roundup of European floor-and-roof systems

Concrete Products, V. 62: No. 10, Oct. 1959, pp. 41-47; No. 11, Nov. 1959, pp. 38-43, 60

Describes and provides data on European precast beams; precast slabs; beam and slab combinations; joist and block combinations; and plain block systems. Information is of interest to producers or prospective producers of precast concrete products.

Prestressed Concrete

Computation of prestressed cylindrical shells by the method of prismatic shells (in Polish)

JERZY KRZEMINSKI, *Archiwum Inzynierii Ladowej* (Warsaw), V. 5, No. 3, 1959, pp. 285-306
Reviewed by STEVEN GALEZEWSKI

A generalization of the method of substitute prismatic shells and its application in the design of any rectilinearly prestressed cylindrical shells is shown. The methods presented in the paper as applicable to both short and long shells. In conclusion a numerical example of a shell of moderate length is given.

Prestressed beams with fiber glass reinforcement (in Polish)

STANISLAW KAJFASZ, *Archiwum Inzynierii Ladowej* (Warsaw), V. 5, No. 3, 1959, pp. 321-346
Reviewed by STEVEN GALEZEWSKI

The test results of 19 concrete beams, 93 in. in length, reinforced with glass fiber cords are discussed. Details of anchorage and tensioning methods are described. The causes of poor efficiency of the glass fiber reinforcement are pointed out. The paper is concluded with remarks on the direction of future investigations.

Continuous precast-prestressed concrete bridges

ALAN H. MATTOCK and PAUL H. KAAR, *Journal*, Research and Development Laboratories, Portland Cement Association, V. 2, No. 1, Jan 1960, pp. 23-27
AUTHORS' SUMMARY

The highlights of an extensive laboratory investigation of continuous precast-prestressed concrete bridges is presented. The type of bridge under study involves I-shaped girders without end blocks and with straight prestressing tendons. The girders are connected to form an integral bridge unit by a cast-in-place deck slab. Continuity from span to span is obtained for live loads by placing deformed bar reinforcement longitudinally in the deck slab across the intermediate piers supporting the girders.

Shear strength of post-tensioned prestressed concrete beams

R. H. EVANS and A. H. H. HOSNY, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 112-132
AUTHORS' SUMMARY

The paper is based on a study of 93 shear failures in prestressed concrete beams. The factors affecting the ultimate shear strength are discussed with particular reference to the amount of prestress and the degree of bond. The possible modes of shear failure are by shear compression, diagonal crushing of the web, and shearing of the compression zone. The ultimate shear strength is discussed from the points of view of the ultimate nominal shear stress and the ultimate shear moment. Semi-rational expressions are recommended for each method. The limits of flexural and shear failures are discussed and presented graphically. In view of the nature of the shear failures, which may take place suddenly, the diagonal cracking stresses are examined. A simple expression is recommend-

ed to safeguard against the appearance of any diagonal tension cracks.

Ultimate flexural strength of post-tensioned grouted rectangular beams

G. S. RAMASWAMY and S. K. NARAYANA, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 14-20

AUTHORS' SUMMARY

Sums up the experiments reported by various investigators and records an attempt to deduce formulas for the lever arm and resisting moment of post-tensioned rectangular beams by fitting a suitable curve to the experimental results using the method of least squares. The present method marks an advance over the previous work on the subject in that a single expression is presented for the lever arm over the entire range of under-reinforced and over-reinforced beams.

New technology for grouting prestressed concrete beams at low temperatures (in Russian)

G. S. FISHER, G. V. KUNI, and K. A. KHLEBNIKOV, *Avtomatika Dorogi*, V. 22, No. 5, 1959, p. 6

ROAD ABSTRACTS Oct. 1959

An electrical method is described for heating prestressed concrete beams to a sufficient temperature to make possible effective grouting at low temperatures. The prestressing cables were heated to a temperature of 30 C. A table of temperatures at beam ends and center is presented with instructions on the method of applying the current. As the air temperature during the experiments described did not fall below 0 C further research is being carried out.

Experiments on the torsional strength of prestressed concrete

HENRY J. COWAN, *Proceedings*, Third Congress, Fédération Internationale de la Précontrainte, Berlin, 1958, pp. 147-157

AUTHOR'S SUMMARY

Nine rectangular beams were subjected to torsion, bending, and combined bending and torsion. Both uniform and eccentric prestressing were applied in post-tensioning with high-tensile alloy steel bars. Results from similar plain concrete beams are given for comparsion. Although prestressing greatly increases the torsional strength of concrete, the failure is sudden and destructive.

Properties of Concrete

Concrete specifications—their interpretation and administration

STANTON WALKER, *Concrete Construction*, V. 4, No. 7, July 1959, pp. 1-4

Specifications for ready-mixed concrete are at present generally based on either performance characteristics (strength, consistency, maximum size of aggregate) or prescription type (ingredients, proportions). The limitation of these two methods of regulating and controlling concrete are discussed. Suggestions are made with the view of improving these specifications to give the buyer or user more assurance that the end product will be of the required quality.

Measurement of the tensile strength of brittle materials

R. BERENBAUM and I. BRODIE, *British Journal of Applied Physics* (London), V. 10, No. 6, June 1959, pp. 281-287

Reviewed by ARON L. MIRSKY

Report of an investigation aimed at establishing a simple, reliable test, to replace the usual pulling-apart test. Three methods were investigated: bending of beams, indentation of square specimens, and diametral compression of disks. Materials used were plaster of paris (99 percent pure), cement, and coal. It was found that results of the last two methods were in reasonable agreement with results of conventional tests, but that results of beam tests were far out of line; this is ascribed to sensitivity to surface conditions of the beams.

While coal was the material of primary interest in this investigation, this paper (and results) will be of interest to all concerned with properties of brittle materials, including cement pastes and motars.

RILEM symposium on bond and crack formation in reinforced concrete, Stockholm, 1957

Proceedings, V. 3, Cement-och Betonginstitutet, Svenska Forskningssinstitutet for Cement och Betong vid Kuncl. Tekniska Hogskolan, Stockholm, 1958, 269 pp.

Presents papers on eight subjects discussed at the symposium plus a round-table discussion on corrosion of steel in concrete. Subjects included are bond between reinforcing bars and concrete, stort-time tests; crack formation in reinforced concrete structures; long-time fatigue tests; influence of bond and cracking on corrosion of reinforcement, on watertightness, and on stiffness; anchorage and splicing by bond; theories of bond and crack formation; simplified rules and specifications dealing with crack width in different countries; and recommendations for testing bond and crack formation.

Damage to concrete surfacings resulting from winter salting (Saltskador pa betongbelaggningar vintertid)

S. G. Bergström, *Bulletin* No. 3, Swedish Cement and Concrete Research Institute (Stockholm), 1959, 43 pp., 8 Kr.
Road Abstracts Oct. 1959

The damage caused by the salt treatment of concrete surfacings in winter is far greater than that caused by the climate alone. The effects which different methods of treatment have on the resistance of concrete to winter salting are discussed. The following conclusions are the results of laboratory and field tests carried out from 1954-1958; (1) Air-entraining agents greatly improve resistance; the air content of the concrete should be 5 to 6 percent. (2) Vibrated concrete should not have a cement content of more that about 19 or 20 lb per cu ft. (3) The brand of cement used is of no particular significance. (4) The grading of the aggregate is of secondary importance. (5) concrete of stiff consistency is more resistant to frost than concrete of loose consistency. (6) Unvibrated concrete of fluid consistency appears to withstand salting satisfactorily. (7) It is doubtful whether post-compaction greatly improves the salt resistance of concrete. (8) The salt resistance of vacuum concrete is also increased by air entrainment. (9) Concrete laid in late autumn should not be salted during the first winter. (10) Membrane curing is at least as effective as curing with moist sand. (11) The worst damage seems to occur during periods of severe and prolonged cold. (12) The results of laboratory freezing tests and practical experience have shown good agreement. Twenty literature references are appended.

Structural Research

Influence of vibration on the creep of ferroconcrete structures (in Russian)

K. K. Shkerbelis, *Akademiya Nauk Latv SSR* (Riga), No. 4, 1956, pp. 27-35
Applied Mechanics Reviews Sept. 1959

The experiments made by the author are described and points established are: (1) that with simultaneous action of static and vibration loads on ferroconcrete structures, the principle of superposition for the determination creep deformation is inapplicable; (2) that vibrations may strongly increase the deformation of creep. It is assumed that the influence of vibration reactions may be taken into account approximately by the coefficient of vibrocreep, linked linearly with the amplitude and vibration frequency.

Recent research on the action of unstressed concrete in composite structures (precast monolithic structures)

O. V. Mikhailov, *Proceedings*, Third Congress, Federation Internationale de la Precontrainte, Berlin, 1958, pp. 51-65
Author's Summary

Describes a series of tests which resulted in the conclusions that in composite sections, where prestressed units are used as reinforcement, the *in situ* concrete does not crack until the strain

reaches about 30 x 10^{-5}, and the construction can deform appreciably only after failure of the prestressed units. The paper also discusses the choice of proportion of precast prestressed unit to *in situ* concrete for maximum strength and economy.

Buckling of columns built of gas concrete blocks

J. Zembrowski, *Przeglad Budowlany*, No. 4, 1958, pp. 165-170

Polish Technical Abstracts No. 1 (33), 1959

Tests are made to determine the ultimate load of gas concrete block columns and these results are then compared to those obtained by formula. Experimental and calculated results show close comparisons.

Work on models in the Cement and Concrete Association

R. E. Rowe, *Journal*, Research and Development Laboratories, Portland Cement Association, V. 2, No. 1, Jan. 1960, pp. 4-10

Author's Summary

The use of models in research and as an aid to design is described and brief details are given of the more important models that have been constructed and tested by the Cement Association in England. Comments are made on the wide range of applicability of model testing and analysis and the interdependence of this technique and fundamental research is stressed.

Shear stresses after cracking (Esfuerzos cortantes despues de la fisuracion)

A. Paez, *Proceedings*, Third Congress, Federation Internationale de la Precontrainte, Berlin, 1958, pp 66-79

Author's Summary

Experiments carried out by the author do not confirm the classical formula for determining the shear stress in a concrete beam, as in 30 percent of the tests failure occurred when the shear stress applied was less than half the load given on the basis of such calculation.

With a view to developing a method of calculation more in keeping with reality, it is concluded that bending moments and shear stresses cannot be considered separately and that the combined action of both may be shown on a single graph from which may be read either the shear strength of a given beam of rectangular section or the longitudinal reinforcement necessary to bear the combined effects of bending moments and shear stresses.

We study stresses with polarized light

Hans Walter, *Consulting Engineer*, V. 12, No. 5, May 1959, pp. 122-127

Reviewed by Aron L. Mirsky

While the basic material in this article is perhaps oversimplified it is of some importance in that it does point out what photoelasticity can accomplish in the office of the structural engineer (at some cash outlay, it is true, but at considerable over-all savings). Examples cited are a large reinforced concrete plate (base) supporting a mine pithead tower, and a complicated reinforced concrete wall with several openings acting as a load-carrying girder in an apartment house.

General

General methods of test and control in the laboratory. V. 1—Geometric and mechanical measurements (Methods generales d'essai et de controle en laboratorie. 1—Mesures geometriques et mecaniques)

Robert L'Hermite, Eyrolles, Paris, 1959, 740 pp., 9965 F.

An exhaustive treatment of a segment of the general field of testing. This first volume deals with organization of the laboratory, use of statistics, and tables of units. It then treats the measurement of length, surface. volume weight, time, force, and deformation. It has two important chapters on extensometry and testing machines. Book contains a good subject and author index. There are copious references to pertinent literature in many languages.

Ready mixed concrete

JAMES A. NICHOLSON, Maclean-Hunter Publishing Corp., Chicago, 1959, 184 pp., $5

A succinct account of all phases of operating a ready-mixed concrete business from planning through sales, day-to-day operation, maintenance, financing, customer relations, and special technical problems. Section headings include: operational fundamentals, special operation considerations, the story of the ready-mixed concrete industry, quality problems and importance of good practices, dealing with customers, delivery control, labor problems, merchandising, maintenance, and office operations. Good reading for both consumer and producer of ready-mixed concrete.

Termite proofing of concrete

F. J. GAY and A. H. WETHERLY, *Constructional Review* (Sydney), V. 32, No. 9, Sept. 1959, pp. 26-28

Noting the risk of penetration of termites into walls and floors made of no-fines concrete, tests were conducted on the effectiveness of a 0.5 percent dieldrin emulsion used as mixing water in the concrete on the mortality of termites. The successful treatment offers a means of protection against termite entry through cracks which develop in dense concrete, but authors conclude that it appears even more useful for preventing termites from making their way through the void system of no-fines concrete.

Concrete research in the Netherlands

A. M. HAAS, *The Reinforced Concrete Review* (London), V. 4, No. 2, June 1956, pp. 127-137

Reviewed by WILLIAM R. LORMAN

Describes modification of the ACI code with regard to flat slab design; the section of the resultant Netherlands Temporary Building Code that pertains to bending moments in columns is based on the British Standard Code of Practice. Summarizes 17 research projects currently under the auspices of the Netherlands National Council for Applied Research; basic research in concrete is conducted at the University of Delft. Discusses a simplified method for designing concrete shell roofs. The article ends with a description of a newly developed instrument for measuring workability of concretes having slump values less than 2 in.

Place of portland cement in concrete making

E. SHELLARD, *The Reinforced Concrete Review* (London), V. 4, No. 2, June 1956, pp. 69-90; discussion pp. 90-94.

Reviewed by WILLIAM R. LORMAN

Gives an historical sketch concerning portland cement; this is followed by a similar section on the development of quality controls in the cement industry. In his explanation of the relationship between portland cement and modern concrete technology the author questions the comon supposition that basic principles of concrete mix proportioning are practiced at the construction site. Includes a presentation of recent developments and future possibilities in the area of portland cement, and ends with a description of new methods of transporting this basic construction material.

Discussion covers operational problems in the field.

Note on landslides and on certain methods for consolidation of slopes (Note sur les glissements de terrain et sur quelques procedes de consolidation des talus)

M. FOURNEL, *Annales des Ponts et Chaussees* (Paris), V. 129, No. 2, Mar.-Apr. 1959, pp. 201-226

Reviewed by ARON L. MIRSKY

Describes two methods used successfully to stop massive landslides: (1) reinforced concrete shafts (pins) constructed by drilling to the underlying firm strata through the shifting mass, inserting reinforcement, and concreting; and (2) injecting cement grout for stabilization. Magnitudes of the forces acting on the shafts of method (1) are investigated in an appendix (pp. 219-226).

ACI NEWS LETTER

CONTENTS

March 1960

56th Annual ACI Meeting 1

ACI Mexico City Regional Meeting Registration 4

Construction Volume in 1959-1960 7

Lightweight Continuous Girders Span Airport Terminal Building 15

Positions and Projects 19

Looking Ahead 23

Errata and Addenda 35

Honor Roll 40

New Members 40

Tools, Materials, Services 45

List of Advertisers 48

New York City — March 14-17

56th Annual ACI Meeting

NEW YORK CITY — CONVENTION CAPITAL of the world — will play host to ACI members and guests at the 56th annual meeting of the Institute, March 14-17, at the Commodore Hotel.

The Technical Activities Committee has arranged a program encompassing the interests of the designer, builder, research man, and others in fields related to the concrete industry. Eminent concrete authorities will present about 30 papers at the eight scheduled sessions.

Technical committee sessions will take up the first 1½ days of the convention program. Committee reports will be presented at the first general session on Tuesday afternoon, March 15, by Committee 326, Shear and Diagonal Tension; Committee 401, Specifications for Structural Concrete; Committee 609, Consolidation of Concrete.

Concurrent technical sessions

On Wednesday morning, March 16, the technical sessions will begin with two sessions running concurrently through Thursday noon. Four sessions on Wednesday will be devoted to model tests, highways, materials, and design and structural research. Thursday morning concurrent sessions will feature a symposium on restoration of deteriorated concrete presented by Committee 201, Durability of Concrete in Service, and a design and construction session.

The annual research session will be held Thursday afternoon, March 17, under the auspices of Committee 115, Research. This session

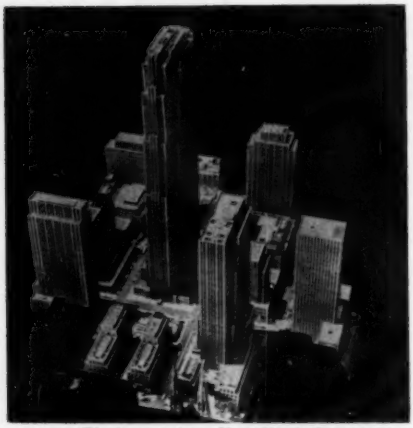


Photo courtesy New York Convention and Visitors Bureau

Bird's Eye View of Rockefeller Center—This "City-within-a-city" is composed of 15 skyscrapers occupying a 12½ acre area. It houses hundreds of prominent business firms, two major radio and TV networks, the AP news service, Radio City Music Hall, 24 restaurants, 200 shops, a government post office, and a 4 acre garden

differs from general convention sessions in that the information is not released for publication. A group of short papers will be presented on research techniques and preliminary results on a number of current projects not yet sufficiently advanced to justify final reports.

Awards luncheon

Eleven presentations will be made at the Awards Luncheon on Wednesday, March 16, along with the announcement of honorary memberships to be bestowed on two prominent ACI members.

Local committee plans

Flanked by a local planning committee of over 50 prominent men, Roger H. Corbetta, Corbetta Construction Co., general chairman of the group, has announced arrangements for a number of added attractions to help make the 56th annual ACI meeting truly a memorable event. Dugald J. Cameron, Concrete Reinforcing Steel Institute, is secretary of the committee, with Admiral John J. Manning, USN (Ret.), of the Concrete Industry Board of New York acting as treasurer.

An interesting feature of the convention will be an informative group of exhibits. Robert K. Lockwood, Sika Chemical Corp., is chairman of the exhibits committee assisted by James Noonan of Praeger and Kavanagh; Dan Morris, Testlab Corp.; and William Griffin, *Engineering News-Record*.

The New York committee extends a cordial invitation to all who attend the convention to be its guests at a "get-together" on Tuesday evening, March 15, at the Commodore Hotel. Every opportunity will be afforded for conventioneers to meet the officers and members of the Board of Direction of the Institute as well as the many prominent national and international members and guests who will be in attendance.

Other "extras" include block reservations for Radio City Music Hall performances on two or three evenings during the convention, attendance at television broadcasts, conducted tours of the United Nations Buildings, and various sightseeing and inspection trips arranged to specific interests of individual groups.

M. J. McMillan, consulting engineer, is chairman of the entertainment committee with the entire local committee cooperating "to roll out the red carpet" for members attending the meeting. Mrs. Elliot A. Haller, assisted by a 12-lady committee, is chairman of special events for the ladies. A "surprise" packet of brunches, luncheons, shopping tours, and sightseeing trips will keep the ladies pleasantly occupied while ACI'ers are attending technical sessions.

Elliot A. Haller, Haller Testing Laboratories, heads up the inspection trips committee, assisted by Boyd Anderson, Ammann and Whitney; Gregory E.

Brooks of Voorhees, Walker, Smith, Smith, and Haines; James E. Halpin, Transit Mix Concrete Corp.; William W. Karl, Lehigh Materials Co.; John M. Kyle, Port of New York Authority; Frederick S. Merritt, *Engineering News-Record;* William H. Mueser of Moran, Proctor, Mueser, and Rutledge; and R. G. Watson, Universal Atlas Cement Co.

Active participation of local universities is assured with Brother Amandus Leo, FSC, Manhattan College Engineering School, heading up the educational committee. Milton Alpern and Esmond Shaw of Cooper Union; Admiral W. Mack Angas, USN (Ret.), and Robert W. McLoughlin of Princeton University; Sidney Borg, Stevens Institute of Technology; and Olindo Grossi, Pratt Institute are working on this committee. On the same committee are Jewel M. Garrelts and James Grote VanDerpool, Columbia University; Paul Hartman, City College of New York; William S. LaLonde, Jr., Newark College of Engineering; James Michalos, New York University; Charles E. Schaffner, Brooklyn Polytechnic Institute; and Joel Wiesenfeld, Rutgers University.

Fred J. Driscoll of George F. Driscoll Co., heads up the publicity committee assisted by Rear Admiral Martin W. Kehart, representing the Society of American Military Engineers, and Emil H. Praeger, of Praeger and Kavanagh, representing the American Society of Civil Engineers. Membership promotion committee is under the chairmanship of Jacob Feld, consulting engineer, assisted by Max Abramovitz of Harrison and Abramovitz; Peter R. Foss, W. J. Barney Corp.; Ernst Gruenwald, Lone Star Cement Corp.; L. D. Long of Gulick-Henderson Testing Laboratories; and W. J. McGinniss, Pratt Institute.

George F. Ferris, Raymond International, Inc., is chairman of the finance committee with H. T. Noyes, Turner Construction Co.; William H. Mueser;

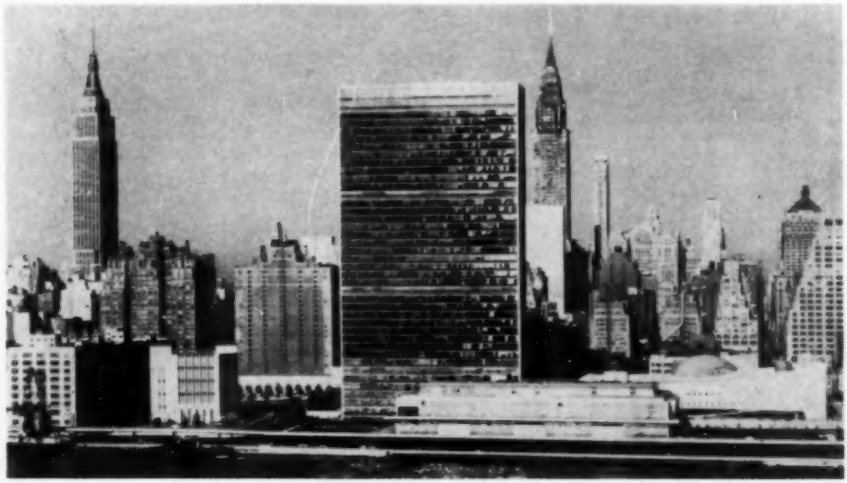


Photo courtesy New York Convention and Visitors Bureau

The United Nations rises majestically from the banks of the East River. Photo shows the 39-story Secretariat office building; adjoining it is the impressive shallow-domed General Assembly building. In the background to the left, is the Empire State Building and to the right, the Chrysler Building

Admiral John J. Manning; and Roger H. Corbetta working on the committee.

Others working on the local committee are: W. A. Blaha, Forbes Fireproofing Corp.; Waldo G. Bowman, *Engineering News-Record;* George N. Cohen, Euclid Contracting Co., representing the Concrete Industry Board of New York; Clayton L. Davis, Universal Atlas Cement Co.; William Eipel, Eipel Engineering; A. L. Glassett, W. J. Barney Corp.; Frank Kelly, Colonial Sand and Stone Co.; William J. McIntosh, Portland Cement Association, representing the Concrete Industry Board of New York; J. C. McClure, Universal Atlas Cement Co.; A. F. Moore, Penn-Dixie Cement Co.; Anton Tedesko of Roberts and Schaefer; Maxwell Upson, Raymond International, Inc.; and Carl Youngdahl, Cement League (BTEA).

Points of interest

Skyscrapers, theaters, museums, stores, special events in the world of music and sports, and of course, the indefinable desire of people who "just want to see the big city," draws 14,000,000 visitors a year to New York City.

The local committee wishes to call attention to Frank Lloyd Wright's recently completed Gugenheim Memorial Museum as a "must" for those interested in modern design and unusual adaptation of concrete construction.

Another of the most recent developments is the huge civic project, costing approximately $205 million, known generally as Lincoln Square. It will contain "a city within a city." There will be incorporated into this project a center for the performing arts, including an opera house, a philharmonic

MEXICO CITY REGIONAL MEETING

By the way, did you wonder where the registrants came from at the ACI 12th Regional Meeting in Mexico City, Nov. 2-5, 1959 (News Letter section, February, 1960, ACI JOURNAL)? Here is a capsulized version of the registration statistics.

MEXICO

Mexico, D. F.	212	Chihuahua	2
Monterrey	22	San Luis Potosi	2
Guadalajara	10	Sonora	1
Veracruz	7	Nuevo Leon	1

UNITED STATES

United States (not specified)	20	Arizona	1
California	12	Georgia	1
Illinois	10	Indiana	1
Texas	9	Iowa	1
Michigan	8	Massachusetts	1
Louisiana	5	New Mexico	1
Florida	4	Missouri	1
New York	4	Nevada	1
Colorado	3	Oklahoma	1
Kansas	2	Tennessee	1
Mississippi	2		

OTHER COUNTRIES

Cuba	3	Columbia	1
Germany	3	Republic of Panama	1
Venezuela	2	Puerto Rico	1
Canada	1		

hall, theater for dance, repertoire drama theater, library-museum, and Juillard School of Music. The center will also include a new midtown campus for Fordham University. A huge housing development will round out the project.

The design for the performing arts center is being accomplished through the utilization of structural concrete. Ground has already been broken, initiating construction work. At convention time, the project shall have been sufficiently advanced to the point of reviewing interesting models that will show the scope and magnitude of Lincoln Square.

One of the prime purposes in arranging conducted tours through the United Nations Buildings, was to call attention to the international influence on the edifice containing the United Nations activities and facilities.

Individuals interested in details of these interesting projects may be afforded an opportunity for intimate discussion with the designers, builders, and operators thereof according to local committee plans.

The approaching completion of the great airport known as New York International Airport (Idlewild), contains a most interesting and fascinating set of facilities and accommodations that attracts countless thousands of people. The major airlines, both national and international, are serviced by terminal facilities incorporating the most daring and modern construction in reinforced concrete. For those interested, an informative trip is contemplated.

New York's waterfront is developing a series of interesting structures, such as the much publicized Pier 57, with its dry "basement" under the main pier. The substructure is composed of three concrete "boxes" which were fabricated many miles away from New York, towed to the site, floated into position, and sunk onto a prepared pile foundation.

Pier 40, another interesting steamship pier, is now in the process of construction and is designed entirely of huge, precast, prestressed structural members. This project will be well advanced in March.

These are only a few of many interesting projects of equal interest recommended as "points of interest" for Institute members attending the 56th annual meeting.

Feld assumes chairmanship of ACI Committee 336

Jacob Feld, New York consulting engineer, has accepted chairmanship of ACI Committee 336, Combined Footings. He succeeds Paul Rogers of Paul Rogers and Associates, Chicago, chairman of the committee since 1958.

An ACI member since 1944, Dr. Feld has contributed generously to ACI committee work. He was a member of ACI-ASCE Committee 327, Ultimate Load Design, and is active on ACI Committee 622, Formwork for Concrete. He has written many scientific and technical papers for German, Australian, and American periodicals, four of which have been published in the JOURNAL.

Dr. Feld has been active in consulting work for the past 35 years. Among his recent, unusual concrete work was the structural design and coordination of the Guggenheim Museum in New York City.

Construction industry conference

The Chamber of Commerce of the United States will sponsor a National Construction Industry Conference, March 10-11, at the Chamber of Commerce Building, Washington, D.C. The purpose will be to discuss ways to promote progress in the 1960's.

Persons who want to attend should write the Chamber's Construction and Civic Development Department, Chamber of Commerce of the United States, 1615 H St., N.W., Washington 6, D.C.

Another First in Building Design *created by*

Reinforced CONCRETE

The Hartford Building, Western Department Headquarters of the Hartford Fire Insurance Company Group, Chicago, Illinois
Architects and Engineers: Skidmore, Owings, and Merrill, Chicago, Illinois
General Contractors: George A. Fuller Company, Chicago, Illinois

A unique example of reinforced concrete's greater design flexibility will be the new 20-story, $20,000,000 Hartford Building now under construction in Chicago. Described as another first in office building design, this unusual reinforced concrete and glass structure will have curtain walls recessed 4 feet to provide canopies above each floor to shade office areas from the glare of sun and sky.

For nearly every type of building, reinforced concrete is the most creative, flexible construction medium. Its "plastic-like" qualities let you mold and form structural designs to meet almost any requirement. Too, it is lower in first cost—lower in maintenance cost. And with all materials readily available from local sources, projects start on time and finish on schedule.

Before you design or build any type of structure, investigate this more flexible, economical, and timesaving method of construction.

Concrete Reinforcing Steel Institute
38 South Dearborn Street, Chicago, Illinois

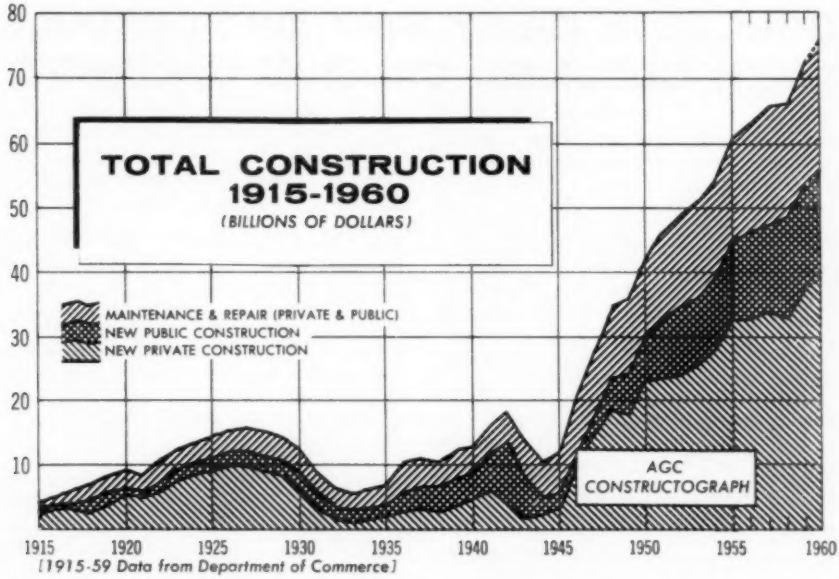
Construction Volume Totals $73 Billion in 1959 for New Record --- May Reach $76 Billion in 1960

CONSTRUCTION VOLUME IN 1959 registered its greatest annual increase in 10 years, climbing to a total of $73 billion, and prospects are bright for another record-breaking year in 1960, the Associated General Contractors of America stated in its annual year-end review and outlook statement.

The 1959 total, consisting of $54 billion in new construction put in place and an estimated $19 billion in maintenance and repair operations, was sparked by a sharp increase in residential volume and moderate rises in most other major types of construction.

Thus construction, as the nation's largest production activity, broke dollar volume records for the 14th successive year, continuing to account for more than 15 percent of the gross national product, and for some 15 percent of total employment, directly and indirectly.

A total of more than $76 billion is forecast for 1960, depending on settlement of the steel strike and other factors, made up of $56.1 billion in new construction and about $20 billion in maintenance and repair. The figures do not include work in Alaska and Hawaii, nor overseas construction performed by the American government and private enterprises.



Construction in 1959 continued the steady expansion it has shown during the postwar years, setting its 14th consecutive annual record with increases of more than 10 percent in the dollar volume of new construction and more than 7 percent in maintenance and repair work

Columbia Calcium Chloride, effective all year, is especially beneficial in concrete when temperatures drop below 70°.

SPRING CHILL SLOWING DOWN YOUR CONCRETE JOBS? STAY ON SCHEDULE WITH COLUMBIA CALCIUM CHLORIDE

Warm spring days are almost here. But don't be caught off guard. There are still plenty of days—and nights—ahead when temperatures will skid below 70°. And you're still faced with the problem of keeping jobs on schedule in spite of the lag in concrete set caused by these low temperatures. You can keep cold weather jobs *moving* by adding Columbia Calcium Chloride at the rate of 2% by weight of cement to your mix. Columbia Calcium Chloride gives you these time-and-profit-saving benefits:

Higher Early Strengths—At 40°F, you get 3-day strength in 1 day, 7-day strength in 3½ days. There's no cold weather lag in strength gain; your job stays on schedule.

Faster Initial Set—Under normal conditions, Columbia Calcium Chloride cuts initial set time from 3 hours to 1 hour. At lower temperatures, the effects are even more pronounced. You get finishers on and off the job faster, avoid costly overtime.

Early Form Removal—Rapid strength gain permits removal and re-use of forms in about half the normal time.

Are you getting these Columbia Calcium Chloride cold weather benefits on your concrete jobs? If not, better analyze your batching procedure or contact your ready mix supplier today. Specify Columbia Calcium Chloride.

For more information on Columbia Calcium Chloride, contact our nearest District Sales Office or write our Pittsburgh address. *You'll like doing business with Columbia-Southern.*

COLUMBIA-SOUTHERN CHEMICAL CORPORATION

A Subsidiary of Pittsburgh Plate Glass Company • One Gateway Center, Pittsburgh 22, Pennsylvania

DISTRICT OFFICES: Cincinnati • Charlotte • Chicago • Cleveland • Boston • New York • St. Louis Minneapolis • New Orleans • Dallas • Houston • Pittsburgh • Philadelphia • San Francisco

IN CANADA: Standard Chemical Limited

The AGC based its outlook on studies of official governmental figures and information from authoritative private sources. Basic assumptions are that costs will not rise appreciably, materials will be plentiful, no prolonged work stoppages will occur in basic industries, and that investment in construction will not be seriously retarded in the increasing competition for capital in the tight money market.

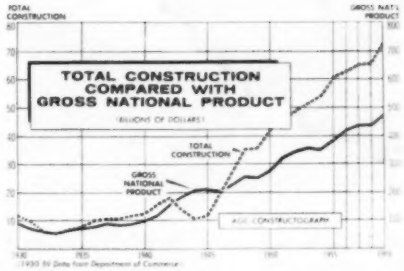
1959 growth exceeds expectations

Construction volume in 1959 increased 10 percent over the 1958 total for the largest year-to-year rise since 1950, considerably exceeding most forecasts made at the beginning of the year.

Private construction, propelled by a spectacular spurt in residential activity, rose 13 percent to $37.8 billion, reversing a 4-year trend when private construction as a whole had about leveled off. Residential building rounded out the year at $22.2 billion for an over-all increase of 23 percent.

Nonresidential private building remained near the 1958 level at $8.6 billion, with rises in commercial, religious, and social and recreational construction offsetting a continued decline in industrial building.

Private industrial building continued to reflect effects of the 1958 recession, as well as the steel strike, dropping 18 percent to about $2 billion, but a recovery was in sight by year's end.



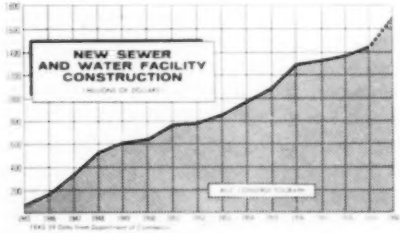
The increase of almost 10 percent in the total volume of construction in 1959 over 1958 was greater than the estimated rise in the gross national product

Public utilities, a mainstay in private construction, remained stable at the high level of $5.1 billion.

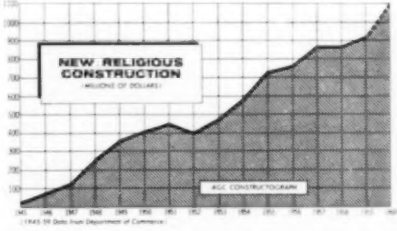
Public construction rose 5 percent to $16.2 billion in 1959, with most major categories sharing in the increase.

Highway construction, the largest single category of public works increased 5 percent to $5.8 billion, although its momentum was slowed by the crisis in financing the long-range federal-aid program.

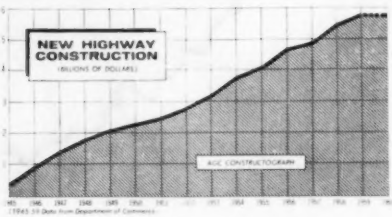
Other state and local public works, such as sewer and water facilities, hospitals, public service enterprises, and administrative buildings, showed moderate increases. Educational building, however, declined 7 percent to $2.7 billion in the face of a continuing shortage of classrooms.



The need for increased construction of new sewer and water facilities continues, and there should be a substantial gain in this category in 1960



The building of churches and other religious structures is expected to maintain the steady increase shown in recent years



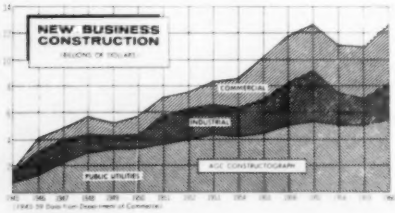
Highway construction in 1960 will level off at about the rate attained in 1959. The need for increased construction of new sewer and water facilities continues, and there should be a substantial gain in this category in 1960

In the programs financed principally by the federal government, military construction increased 6 percent to $1.5 billion, and conservation and development facilities rose 13 percent to nearly $1.2 billion.

Outlook for 1960

The estimate of more than $56 billion in new construction in 1960 hinges on the basic assumption that the steel strike will not be resumed, and that uninterrupted production will bring structural and other steel types required for construction back into balance by the time activity reaches its seasonal peak.

While residential activity dominated the 1959 construction scene, the reverse is expected in 1960, with strong advances in all private nonresidential building.



Business construction in 1960 should resume the rising trend which was interrupted 2 years ago by a sharp decline in private industrial construction, now turning upward again

The tightening credit situation, already affecting the residential market, will be the major damper on the volume of construction that could be undertaken in 1960, which might otherwise be even a larger construction year.

Significant features of the private construction picture in addition to a decline in housing, will be a sharp increase in industrial building, a continuing increase in commercial construction, and a high level of state and local public works. It is believed that a considerable amount of work tentatively scheduled for 1959 is being carried over into 1960 due to steel shortages.

The 1960 outlook by major categories is as follows:

Residential is expected to show a 4 percent decrease to $21.4 billion in residential building, with about 1,200,000 new units started, compared with an estimated 1,350,000 starts in 1959. Within this category, however, apartment construction will continue to advance.

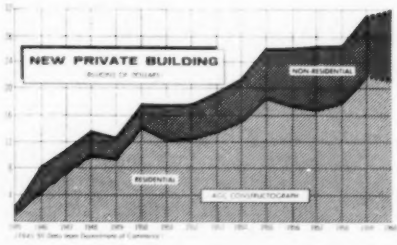
Commercial construction should increase more than 15 percent to about $4.5 billion. An office building boom will be carried over into 1960, and the housing boom of 1959 will exert heavy pressure for suburban stores and other commercial establishments.

Religious structures probably will reach the $1 billion mark in total for the first time.

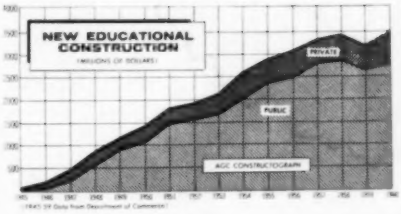
Public utility facilities should resume an upward climb, possibly reaching $5.5 billion, led by increases in construction by telephone and telegraph companies and the gas industry.

Industrial building, which declined sharply during the past 2 years, should expand 30 percent to more than $2.5 billion as business concerns increase plant and equipment expenditures.

Farm construction, after a moderate rise in 1959, is expected to decline more than 10 percent.



New private construction is expected to continue to expand in dollar volume in 1960, with larger expenditures for non-residential building activity more than offsetting a drop in residential construction



Only a slight increase in new public educational construction is anticipated during the coming year, but private educational building activity is likely to show a higher percentage of gain, though smaller in volume

Highways and streets are expected to remain at near the record-breaking figure of $5.8 billion. While some momentum in the expanded highway program will be lost under the influence of federal contract controls and reduced authorizations, it is believed that a carry-over of some projects which were delayed by the steel strike will keep construction work near 1959 levels.

Public educational building, which declined in 1959, should experience a mild recovery, reaching $2.8 billion.

Sewerage and water facilities should continue advancing under the heavy pressure of residential building and population incrases, reaching $1.7 billion, a 10 percent rise.

Military construction, with emphasis still shifting toward missile base facilities, should hold close to its 1959 level of nearly $1.5 billion, depending upon budgetary actions of the government. The same holds true for conservation and development, which has gradually increased in recent years, totaling $1.2 billion in 1959.

1959 mineral production

Despite a slight rise in the total value of mineral output in the United States in 1959, a number of commodities—principally metals where strikes suspended operations—did not follow the upturn in economic activity, the Bureau of Mines, Department of the Interior, recently reported in a year-end summary.

The Bureau, in preliminary figures, estimated the value of mineral production for 1959 at $17.1 billion, compared with 1958's $16.5 billion. The record, $18.1 billion, was established in 1957.

Mine and quarry production of nonmetal construction minerals was higher. Stone, sand and gravel, clays, and cement gained from 10 to 15 percent. The value of nonmetals output was $3690 million, compared with $3340 million in 1958.

Construction established a new record in 1959, increasing about 15 percent over 1958 despite the steel strike, shortages in highway building funds, and difficulties in home financing. Output of stone, sand, and gravel in 1959 paralleled the upward construction trend and reached new highs.

Blast-furnace slag for use in portland cement was in high demand, but an acute shortage developed because of the steel strike. Increased construction activity resulted also in greater demand for cement, and production in 1959 was 9 percent higher than in 1958

and 4 percent higher than the 1956 peak. Four new cement plants were built and others were expanded. Annual capacity reached 410,000,000 bbl. Gypsum and gypsum products neared new highs because of residential construction.

Clay output increased about 10 percent because of greater demand for refractories, a continued high level of activity in the building industry, and the development of new processes for making clay-bonded lightweight building block.

Researchers testing latex mortar for thin-patching

Michigan State Highway Department researchers are quietly optimistic about a new "rubber" base latex mortar now being tested which may solve the age-old problem of thin-patching structural concrete.

Although not actually rubber, but a rubber derivative, liquid latex emulsion is added to concrete during the regular mixing process, which then results in a more pliable, chemical resistant finished product.

Because of the latex mortar's pliable nature, it permits patchwork at a minimum thickness of ½ in., where in past years patching operations consisted of removing a large portion of the original concrete, generally to a depth of 4 in., to assure an adequate bond with the concrete base. This is a costly method—in labor, materials and time—and not always successful.

In its first rigorous field test, the latex mortar was used in the fall of 1957 to patch a disintegrating, heavily-traveled bridge deck on a bascule bridge at Cheboygan. A minimum of ½ in. of deteriorating concrete was removed and replaced with an equal amount of latex mortar.

A year later, after approximately 100 freeze-thaw cycles, the patch was examined for loss of bond and durability and was judged "very satisfactory." Other experimental latex mortar patching preparations used on the same bridge deck failed in varying degrees during the same period of time and were replaced with the successful preparation.

A modified latex mortar, which was proved stronger in the laboratory, and other modified latex mortar preparations were used for patchwork on a bascule bridge at St. Joseph in August, 1958. Results of this test are still inconclusive.

In laboratory tests, the successful latex mortar preparation was subjected to 250 freeze-thaw cycles, equivalent to 2½ years in the field, with no loss in weight (durability).

Additional laboratory tests on the experimental latex mortar indicate that it has increased resistance to salt action, a lower water-cement ratio with increased workability, increased compressive, tensile and flexural strengths, and a reduced water absorption, resulting in greater concrete strength.

Foster and Cafarelli expand facilities

The firm of Foster and Cafarelli, New York City consulting engineers, has announced expansion of its facilities with the opening of a new office on Long Island, N.Y.

BRI 1960 spring conference

Major technical programs on paints, adhesives, and masonry cavity walls; sessions on operation and maintenance costs, air cleaning and purification in buildings; and a plastics information workshop are scheduled for the 1960 spring conferences of the Building Research Institute to be held April 5-7 in the Statler-Hilton Hotel in New York City. Milo D. Folley of the architectural firm of Sargent, Webster, Crenshaw and Folley, Syracuse, N.Y., will serve as general conference chairman.

Concrete Hyperbolic Parabaloid Roof

Partially completed fireproof shopping center. Each of the 44 umbrella units is 48'6" x 46'3" and is supported by a single column. The completed building is 196' x 511'.

Provides Large Unobstructed Floor Areas

At Bloomington, Minnesota, this new shopping center has been completed employing a very modern concrete hyperbolic parabaloid roof design—the first of its kind in the Minneapolis area. This type of roof design for single story structures provides large unobstructed floor areas at low cost.

Contractor planning on the job was precise. Careful scheduling and the use of Lehigh Early Strength Cement made it possible to strip and re-use the unique concrete form system in less than half the time which would have been required with regular cement. Only four sets of forms were needed. Eight units—or bays—were poured per week.

This is another example of the advantages of Lehigh Early Strength Cement and modern concrete construction. Lehigh Portland Cement Company, Allentown, Pa.

LEHIGH CEMENTS

Owner: Bloomington Development Co., Bloomington, Minn.

Architects: Manuel Morris & Robert E. Sixta Assoc., Kansas City, Mo.

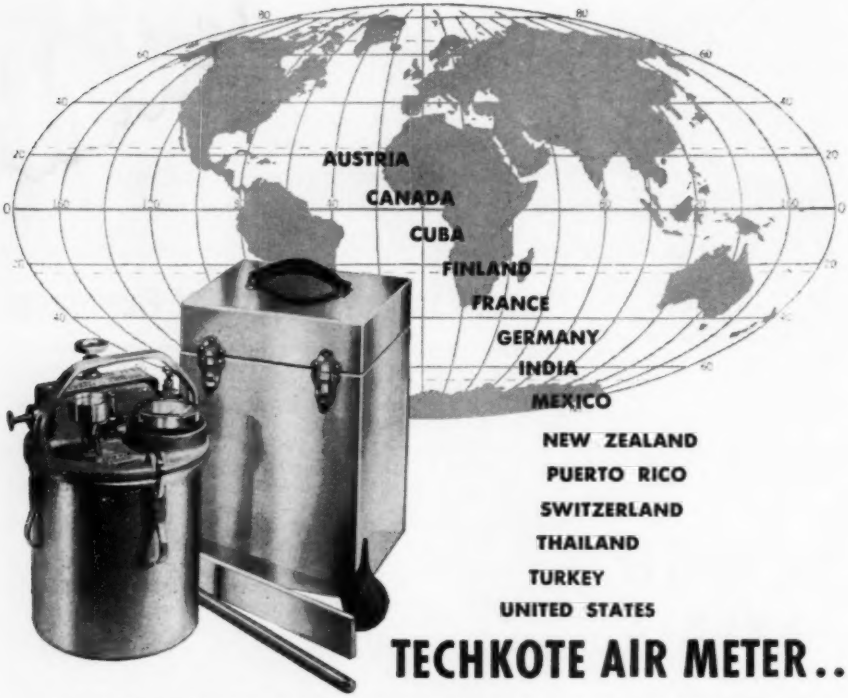
Structural Engr.: Dutton Biggs, Kansas City, Mo.

Contractor: George Madsen Construction Co., Minneapolis, Minn.

Ready Mix Concrete: Twin City Ready Mix Concrete Co., Minneapolis, Minn.

As set of forms is lowered, workmen place supplies of reinforcing on it. Form serves as elevator to carry bars to roof for assembly. Each half of the form weighs 4 tons. Four sets of forms were used cyclically for an efficient construction schedule.

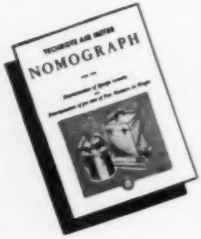
Other workmen prepare reinforcing for more roof sections on top of completed concrete "dunes." Concrete shell is 3" thick.



TECHKOTE AIR METER..

FIRST CHOICE AROUND THE WORLD

The Techkote Air Meter now provides a multi-range testing instrument that vastly increases the usefulness of the air meter. It is now possible to measure accurately—within a fraction of a degree—entrained air with one instrument on numerous materials such as lightweight concrete, mortar, plaster and soil, in addition to regular concrete.



NOW in both ¼ cu. ft. and ½ cu. ft.

This outstanding new Multi-Range feature, together with the Nomograph and many other exclusives of the Techkote Air Meter, offers a combination unequalled in this type of equipment. TO BE SURE...USE THE FINEST!

PRESSTITE DIVISION
AMERICAN-MARIETTA COMPANY
Western District
600 LAIRPORT ST. • EL SEGUNDO • CALIFORNIA

Lightweight Continuous Girders Span Airport Terminal Building

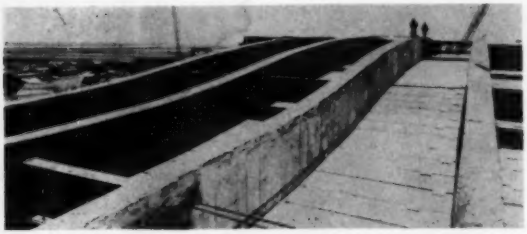
THE MAJOR PART of the roof of Eastern Air Lines' passenger terminal building at New York's International Airport, Idlewild, N. Y., rests on 16 massive, slightly arched girders which rise 9 ft at their centers and are supported by only three columns in the terminal's 230 ft width.

Nearing completion, the $20 million terminal is a 375 x 280-ft, three-level building which is slightly trapezoidal in shape. Passengers walk through the 126 x 230-ft column-free lobby to either side of the building and then along one of two 35 x 400-ft glass enclosed fingers to board their planes. Across the front of the building a 50-ft wide section permits the discharge and loading of passengers from and to cars and buses right inside the building.

The consulting engineers, Seelye, Stevenson, Value & Knecht, recommended a lightweight aggregate concrete to save weight since the building is supported on 6000 pressure creosoted timber piles—some of them penetrating 70 ft into the soil below. Each pile has a design load of 25 tons. All of the 20,600 cu yd of concrete in the building was made of Lelite aggregate, with the exception of the foundation and the first floor slab. The lightweight concrete weighed 110 to 116 lb per cu ft which, compared to 150 lb per cu ft for ordinary stone concrete, represents a saving in the deadweight of approximately 22 percent.

The 8-ft 8-in. deep girders which support the roof are spaced 15 to 18 ft apart and extend above it to form an interesting pattern when viewed from the air or the interior of the huge lobby. Although only 126 ft spans were required to provide a column-free lobby, each of the 16 girders was cast for its entire 230 ft length, since it was more economical to utilize a continuous girder supported on three columns. There is a column on either side of the 126-ft lobby and a third column to support the far end of the continuous girder. The girder cantilevers at both ends, 4 ft 5 in. beyond the third column and 15 ft 3 in. on the lobby side. These structural members are 2 ft 10 in. wide at the center and taper to a 2 ft width

$20 million Eastern Air Lines Terminal at New York's International Airport

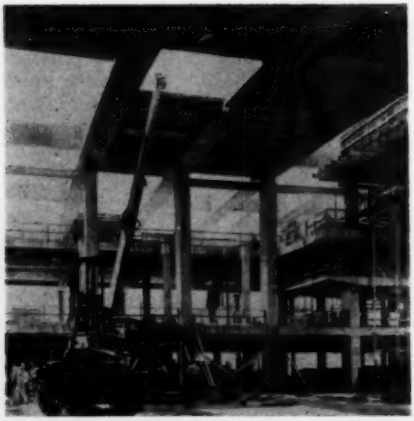


Girders arch slightly at their centers. Each of the 16 girders was cast for its entire 230 ft length since continuous construction reduced maximum deflection in the members and thereby economized on materials

at each end. An 8 in. wide shoulder cast integrally with the girder along the bottom chord supports the 5 in. precast roof slab.

Retarding concrete set simplified construction

Casting the girders presented some construction problems, as specifications required the entire unit to be homogenous. To achieve this objective, the consulting engineer specified the use of Plastiment retarding densifier in the lightweight concrete mix. This additive kept the concrete plastic for approximately 15 hr—long enough so that the entire girder could be cast at one time without any portion of the concrete hardening prematurely. Each girder was cast in 10 to 12 hr without any cold joints in its interior, which would have caused planes of weakness.



Five in. thick precast reinforced roof slabs were placed on 8-in. flanges cast integrally with the girders. While roof slab is being placed, workmen strip side forms from a newly cast girder at the upper right

Starting at both ends, and alternating, the girder form was filled with concrete through ports in the side of the formwork. As it was placed, it was vibrated continuously. The ports were at two levels. Bottom dump buckets emptied into elephant trunks which fed into the ports. This technique facilitated concreting as the engineer's specifications limited the drops to 6 ft in height. Heavy steel reinforcement along the top of the girders would also have slowed concreting if the ports had not been used. The 14-S reinforcing bars (equivalent of 1½ in. square bars) were butt welded by the thermit process. The soffit forms for the girders were mounted on traveling falsework which was lowered and moved for each placement. The side forms, resting on the bottom forms, were positioned by cranes for each girder.

Specifications called for 3-day strengths of 2500 psi and 28-day strengths of 3000 psi. Frequent Schmidt hammer tests were used to check on the concrete strength and cylinders were broken regularly.

The placement of 20,600 cu yd of concrete, much of it during the summer, was carried out without difficulty. The majority of construction was performed during the spring, summer, and winter of 1958. During the hot weather, the proportion of retarder was increased to 1 lb per sack of cement to offset the more rapid rate of hardening of the concrete.

Special consideration for lightweight concrete

The handling of lightweight concrete requires some special considerations. A few rudiments, kept in mind, can produce high-quality lightweight concrete. The following eight points are offered by H. S. Woodward, project engineer for Seelye, Stevenson, Value & Knecht:

1. "It is important for workability that the aggregate be saturated for 24 hr prior to placement, although it should be dry to the touch.

2. "Uniform concrete can usually be produced more easily by keeping the fine and coarse aggregates separate, rather than in a blended mix, to prevent segregation in transit and stockpiling.

3. "At least twice as many fines should be used as would be considered normal in ordinary concrete. This should be at least 50-60 percent by volume of the total aggregate. The lowest possible percentage of fines should be used with the minimal percentage of air to provide workability. A deficiency of fines should be avoided at the other extreme, because the fine material has greater density than the coarse and is important for strength.

4. "Lightweight aggregate is so sharp and angular it is impractical to obtain good workability by using only fines. Low strength mixes would be obtained with normal cement factors.

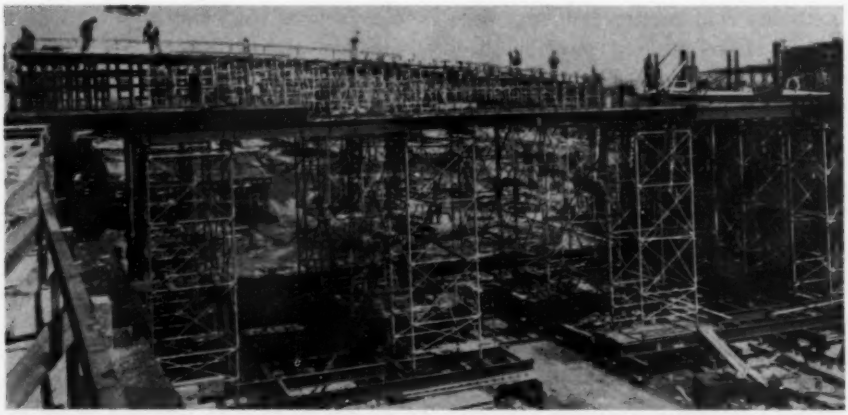
5. "Some internal lubrication is necessary for additional workability. Air entrainment is usually used for this purpose.

6. "Slumps are not comparable to those for heavy concrete. For equivalent workability, lightweight concrete may have 2 or 3 in. less slump.

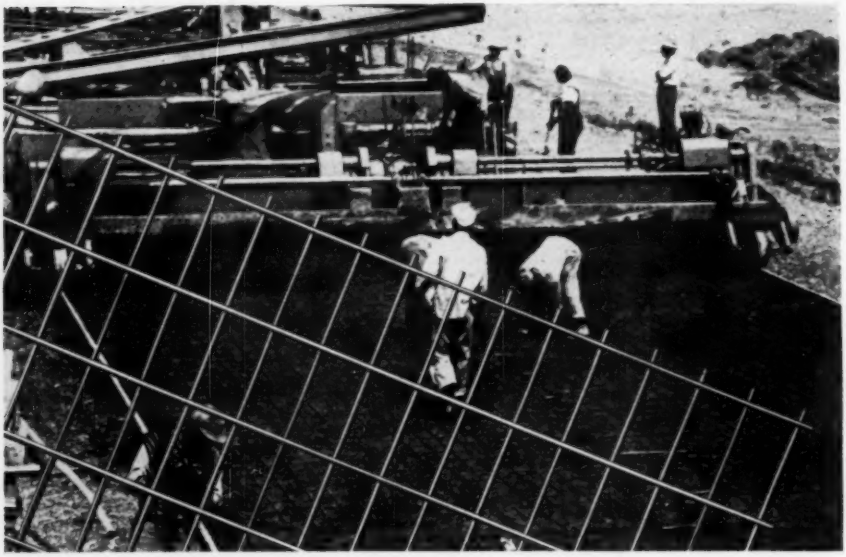
7. "The amount of air entrainment for best results should be about twice as much as that used for conventional concrete. More air entrainment is needed as less of the larger aggregate is used. Air-entraining cements, by themselves, do not produce sufficient air. The usual percentage is 6 to 8 percent. From 1 to 2 oz of air-entraining admixture per bag of cement is usually added. The strength loss resulting from entrained air is about half as much with lightweight concrete as with conventional mixes.

8. "In hot weather where monolithic finishes are necessary or where large

Continued on p. 38



Workmen built 230 ft long soffit forms for girder. After casting each girder, screw adjustments at base of scaffolding are lowered and the entire assembly moved on rails 15 to 18 ft to next girder position. Side formwork, which has openings for placement of the lightweight concrete, was positioned by cranes



Sinews of steel
to strengthen concrete construction

Clinton Welded Wire Fabric

For years, CF&I has worked closely with the construction industry, developing strong welded steel mesh for reinforcing purposes. The result: CF&I-Clinton Welded Wire Fabric.

This rugged mesh gives concrete structures—from bridges and roads to culverts and skyscrapers — maximum strength and durability. Its dependability stems from the high quality of the steel wire used.

CF&I-Clinton Welded Wire Fabric is manufactured to all ASTM specifications and is furnished in either rolls or mats. It is supplied in a wide range of gages and spacings.

For complete information, call our nearest sales office.

CLINTON
WELDED WIRE FABRIC
THE COLORADO FUEL AND IRON CORPORATION

CF&I STEEL

In the West: **THE COLORADO FUEL AND IRON CORPORATION**—Albuquerque • Amarillo • Billings • Boise Butte • Denver • El Paso • Farmington (N. M.) • Ft. Worth • Houston • Kansas City • Lincoln • Los Angeles Oakland • Oklahoma City • Phoenix • Portland • Pueblo • Salt Lake City • San Francisco • San Leandro Seattle • Spokane • Wichita

In the East: **WICKWIRE SPENCER STEEL DIVISION**—Atlanta • Boston • Buffalo • Chicago • Detroit New Orleans • New York • Philadelphia

CF&I OFFICE IN CANADA: Montreal
CANADIAN REPRESENTATIVES AT: Calgary • Edmonton • Vancouver • Winnipeg

7520

Positions and Projects

Southern California Chapter annual meeting, March 30

The second annual meeting of the ACI Southern California Chapter will be held on March 30 at Rodger Young Auditorium in Los Angeles.

Chapter president, J. L. Peterson of J. L. Peterson, Inc., will preside at the business meeting, announcing returns of the chapter's election of officers for 1960.

The chapter met for a dinner meeting on January 20 at the Rodger Young Auditorium. The technical program, arranged by program chairman Robert E. Tobin, presented a panel of qualified speakers in a symposium on lightweight concrete made with manufactured aggregates. Panel members and subjcts were: Dwight F. Roberts, vice-president, Smith-Emery Co., who spoke on materials, proportioning, and testing; John J. Driskell, structural engineer, covered design considerations and economics; and Ed Oberly, formerly Portland Cement Association construction superintendent, discussed handling lightweight concrete in the field.

ACI Oklahoma Chapter active in Southwest concrete conference

ACI cooperated in conducting the 10th annual Southwest Concrete Conference, January 13-14, at Oklahoma State University, Stillwater.

The conference was directed by R. P. Witt of the School of Civil Engineering, Oklahoma State University. The program was planned by a steering committee whose members represented all the fields the conference was designed to serve.

Eight ACI members participated in the program in addition to Professor Witt. Jan J. Tuma, School of Civil Engineering, Oklahoma State University, and Harold Wenzel, Dolese Co., presided at the sessions on January 13. Calvin Garrett, Industrial Concrete Builders, and Stanley Gerlach of Gerlach Co. were among the speakers featured the first day of the program, speaking on "Thin Shell Construction" and "Hidden Costs in Concreting," respectively. Three papers dealing with concrete highway structures, better understanding for greater productivity, and modern trends in beautifying concrete rounded out the first-day sessions.

Richard Jackson of Black and West, Architects, and James H. Sprouse, Master Builders Co., presided at the January 14 sessions, with papers presented by Roy L. Peck, *Modern Concrete;* Harvey W. Wright, Jr., Portland Cement Association; Wyatt L. Wells, Chandler Materials Co.; and James D. Piper, Portland Cement Association. Their papers covered such subjects as concrete pavement designs for municipalities, lightweight aggregate concrete field control, and Russian progress in concrete technology.

Approximately 100 individuals attended the conference, a presentation of the School of Civil Engineering and the Division of Engineering and Industrial Extension, Oklahoma State University. Among cooperating groups were: Oklahoma Ready-Mix Concrete Association, Portland Cement Association, and the concrete industry of the Southwest.

Concrete space structures theme of meeting in Detroit

The Concrete Steel Corp. of Detroit, a subsidiary of Hausman Steel Co., Toledo, Ohio, was host to about 300 architects, engineers, and specification writers at a dinner meeting in Detroit on January 19.

"Concrete Space Structures" was the theme of the program and W. A. Ober-

dick of the College of Architecture of the University of Michigan, Ann Arbor, conducted a brief course on space structures, starting with slabs and proceeding through to hyperbolic paraboloids.

Other speakers on the program were Raymond C. Reese, consulting engineer, Toledo, chairman of ACI Committee 318, Standard Building Code, and Minoru Yamasaki, architect from Birmingham, Mich., who is well known as the designer of the Institute headquarters building and many other outstanding structures.

Prestressed Concrete Institute announces move to Chicago

The Prestressed Concrete Institute has announced the removal of its Florida headquarters and publications office to Chicago. The move from Boca Raton is designed to provide greater centralization of activity and dissemination of information to the prestressed industry according to Randall M. Dubois, president of Freyssinet Co., Inc., New York, who was elected president of the Prestressed Concrete Institute at the 6th annual convention in November.

Other officers elected at the time of the convention were: vice-president, Jacob O. Whitlock, Mid-West Prestressed Concrete Co., Springfield, Ill.; and secretary-treasurer, Charles L. Scott, Jr., Southern Prestressed Concrete Co., Inc., Pensacola, Fla. Directors include: Ross H. Bryan, consulting engineer, Nashville, Tenn.; Elmer D. Clark, Superior Sand and Gravel, Phoenix; R. O. Kasten, Union Wire Rope Corp., Kansas City, Mo.; Charles B. Kiesle, Jr., Raymond International, Inc., New York; Ezra C. Knowlton, Utah Sand and Gravel Products Corp., Salt Lake City; Robert J. Lyman, Atlas Structural Concrete, Inc., El Paso; John K. Zimmerman, Pennsylvania Prestress, Inc., York; Robert A. Matthews, Precast Industries, Inc., Kalamazoo, Mich.

Davisson wins second annual Alfred A. Raymond Award

M. T. Davisson, right, receives award from Maxwell M. Upson

M. T. Davisson, a civil engineering instructor at the University of Illinois, recently received a $1000 check and citation from Maxwell M. Upson, board chairman of Raymond Concrete Pile Co., New York, for winning the second annual Alfred A. Raymond Award.

Raymond established the award last year in honor of its founder "to encourage originality in research and development in the field of foundation engineering." Mr. Davisson's paper, an investigation of the lateral stability of New York City's new Pier 40, was judged the best of 30 papers submitted in world-wide competition.

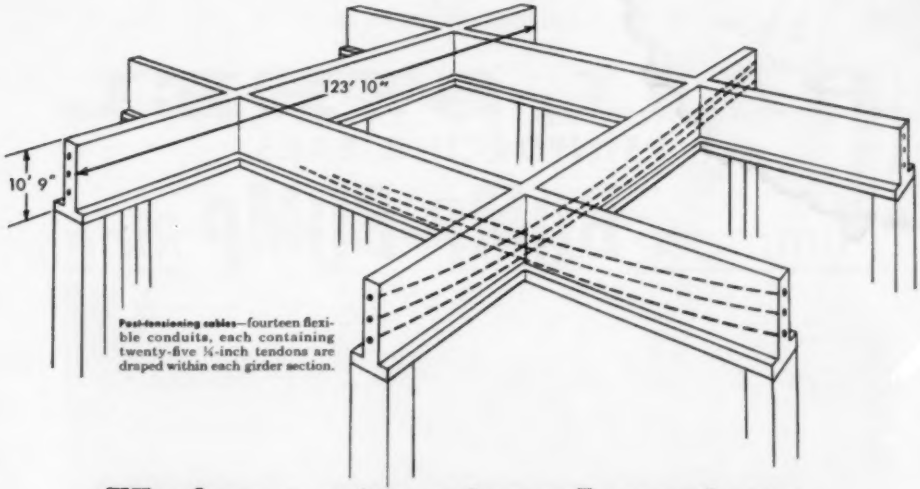
ACI member Davisson received a bachelor's degree from the University of Akron in 1954 and a master's degree from the University of Illinois in 1955.

FIP-RILEM symposium on grouting for prestressed concrete

A symposium will be sponsored jointly by the Federation Internationale de la Precontrainte (FIP) and Reunion Internationale des Laboratoires d'Essais et de Recherches sur les Materiaux et les Constructions (RILEM) on injection grout for prestressted concrete. This symposium will be held at Norges Tekniske Hogskole in Trondheim, Norway, June 20-22.

The program will cover general problems connected with the grouting of post-tensioned structures, composition of grout and methods of grouting, and standard requirements for grouting. Sessions devoted to the results of laboratory and field studies will cover such properties as: fluidity, setting time, stability, shrinkage, bond and

POZZOLITH . . . makes good concrete better


123' 10"
10' 9"
Post-tensioning cables—fourteen flexible conduits, each containing twenty-five ¼-inch tendons are draped within each girder section.

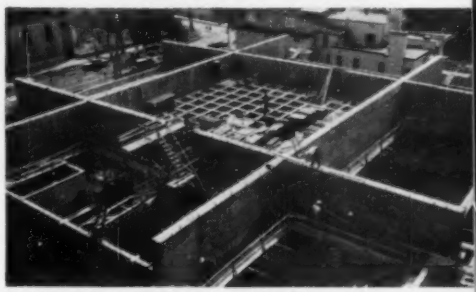
Unique structural system for Utica's newest art gallery

The huge monolithic, intersecting pre-stressed girder system sketched here is the heart of a unique engineering and construction achievement. In a continuous 16-hour placing operation, the girder was cast in place fifty-feet above grade. POZZOLITH was used in the 350 cu. yds. of concrete to meet these rigid requirements:

- 28-day strength of 5000 psi
- slow initial set to avoid cold joints
- extremely high degree of workability to prevent voids and honeycombing in girders crowded with reinforcing steel and post-tensioning cable conduits

In addition, POZZOLITH was used in all job-placed concrete—for foundations, walls and exterior supporting columns to obtain increased workability and minimum shrinkage.

The local Master Builders field man will welcome discussing your requirements. Remember, POZZOLITH concrete is higher in quality and more economical than plain concrete or concrete made with any other admixture.



DESIGNED BY ARCHITECT PHILLIP JOHNSON AND ENGINEERED BY DR. LEV ZETLIN—this concrete tic-tac-toe provides an interior free of columns for Munson-Williams-Proctor Institute Art Gallery in Utica, New York. Contractor: George A. Fuller Company, New York; Supervising Architects, Bice and Baird of Utica. POZZOLITH ready-mix concrete from American Hard Wall Plaster Company, Utica.

The Master Builders Company, Cleveland, Ohio
Division of American-Marietta Company
The Master Builders Company, Ltd., Toronto, Ontario
Represented in foreign countries by:
Master Builders International, Nassau, Bahamas
Division of American-Marietta, C.A.
Branch Offices in all principal cities.

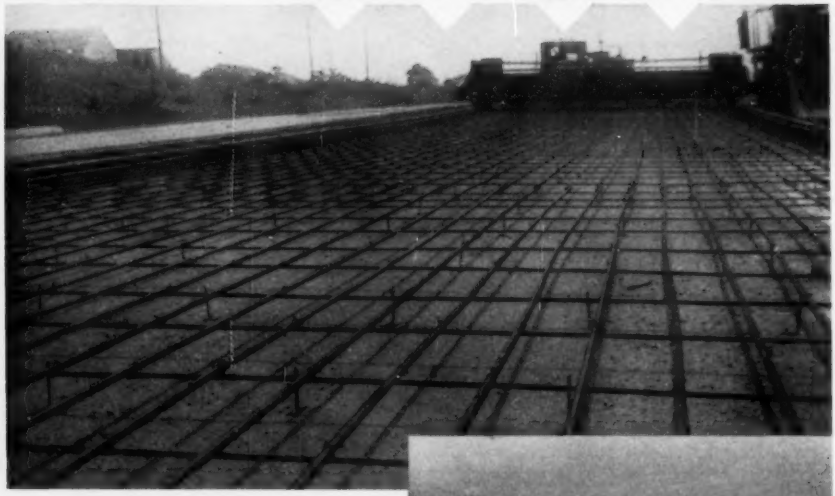
MASTER BUILDERS. POZZOLITH*

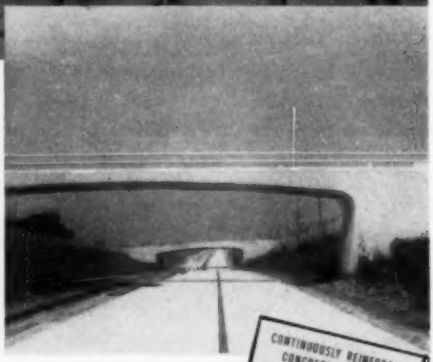
*POZZOLITH is a registered trademark of The Master Builders Co. for its concrete admixture to reduce water and control entrainment of air and rate of hardening.

RAIL STEEL

REINFORCING BARS

Eliminate "BUMP-BUMP" *Ride*





Continuously reinforced concrete pavement with Rail Steel Reinforcing Bars eliminates expansion joints and aggravating "Bump-Bump" ride.

The cost of the rail steel reinforcing bars will be considerably offset by eliminating expansion and contraction joints... by reducing pavement thickness for heavy traffic...by minimizing the cost of subgrade preparation.

Maintenance costs will be reduced by eliminating crack sealing, eliminating mudjacking and undersealing of pumping joints, minimizing corner break repairs and postponing surface roughness and resurfacing.

Concrete highways reinforced with rail steel bars are smoother, longer lasting and more economical—read all about it in Brochure shown at right—write for your personal copy TODAY.

***Write for* YOUR FREE copy TODAY**

RAIL STEEL BAR Association

38 South Dearborn St., Chicago 3, Illinois

other mechanical properties, and frost resistance. An exhibition and demonstration of materials and equipments for grouting will round out the program.

Sacramento schedules institute on nondestructive testing

In response to requests from industries and government agencies on the West Coast, Sacramento State College will conduct a summer institute on nondestructive testing, August 15-26.

This intensive 2-week program of instruction and practice is designed to train personnel in the fundamental principles and proper application of nondestructive test methods. Detailed instructions will be given on theory, procedures, equipment, applications, and interpretation of test indications in terms of material discontinuities and serviceability.

The institute will be planned, supervised and presented by members of the faculty of the Department of Engineering of Sacramento State College, with visiting lecturers representing other organizations contributing in their areas of specialization.

The number of participants is limited. Registration fees of $175 are payable in advance and should be sent (prior to July 1) to: Dr. George N. Beaumariage, Jr., Summer Institute in Nondestructive Testing, Engineering Department, Sacramento State College, Sacramento 19, Calif.

Dewey and Almy appoints Spada

The appointment of Richard T. Spada, Sycamore, Ill., as midwest product sales manager for construction chemicals has been announced by Dewey and Almy Chemical Division, W. R. Grace and Co., Cambridge, Mass. Mr. Spada has been with Dewey and Almy since 1953. In his new post he will be serving Dewey and Almy's midwest distributors of admixtures for concrete.

LOOKING AHEAD

Mar. 3-4, 1960—11th Annual Better Concrete Conference, Iowa State University, Ames

Mar. 7-10, 1960 — 52nd Annual Convention, American Concrete Pipe Association, Fairmont Hotel, San Francisco, Calif.

Mar. 7-11, 1960 — New Orleans Convention, American Society of Civil Engineers, Jung Hotel, New Orleans, La.

Mar. 14-17, 1960 — 56th Annual Meeting, American Concrete Institute, Commodore Hotel, New York, N. Y.

May 4-8, 1960 — Cleveland Convention, American Society of Civil Engineers, Hotel Cleveland, Cleveland, Ohio.

June 20-22, 1960—FIP-RILEM Symposium on Injection Grout for Prestressed Concrete, Norges Tekniske Hogskole, Trondheim, Norway

June 26-July 1, 1960 — Annual Meeting and Apparatus Exhibit, American Society for Testing Materials, Chalfonte-Haddon Hall, Atlantic City, N. J.

July 11-18, 1960 — Second World Conference on Earthquake Engineering, Science Council of Japan, Tokyo and Kyoto, Japan.

July 17-21, 1960—RILEM International Symposium on Concrete and Reinforced Concrete in Hot Countries, Israel Institute of Technology, Haifa, Israel

Aug. 15-26, 1960 — Summer Institute on Nondestructive Testing, Sacramento State College, Sacramento, Calif.

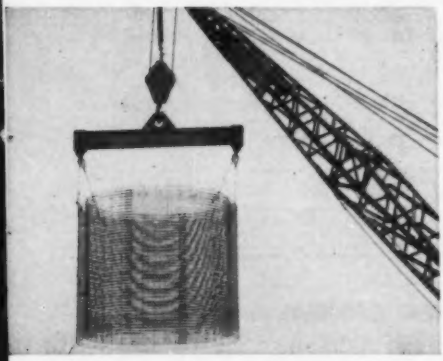
Reinforced Concrete Pipe specified for

The contractor was able to lay 15 to 20 sections of 8-foot pipe in 8-hour work shifts. This rapid progression indicates the exactness of the sections of concrete pipe furnished to the job. The contractor used care in keeping the trench walls vertical and narrow. Since the load-bearing capacity of the pipe is greatly influenced by the width of the trench, this type of installation is desirable and can be accomplished without special labor or equipment.

Visintine & Company and The Complete General Construction Co., Columbus, Ohio—Contractors

Price Brothers, Columbus, Ohio—Pipe Manufacturers

40-foot depth on Ohio Interstate Highway



The 2 cages of American Welded Wire Fabric are tied together at both the top and bottom with ⅜" diameter stirrups. These stirrups increase the ultimate strength of the pipe and resist diagonal tension at top and bottom sections. If the circumferential steel were not accurately spaced, it would be difficult to place the stirrups in the positions required for best performance. This consideration, plus the over-all economy of using readily fabricated American Welded Wire Fabric, led to its selection.

Over-all view of the trench digging and pipe laying operations. You will notice that the 40-foot trench is open cut using a dragline down to the first level and then a back hoe to the 40-foot level. This sequence of operations enabled the trenching operation to proceed very rapidly. The back hoe digging the final trench provided the extremely straight and narrow trench for best installation.

In Columbus, Ohio, work is progressing on one leg of the important new North-South Freeway. 96" dia. reinforced concrete pipe was specified for a 40-foot depth installation. This was included in one of the largest contracts ever let by the state of Ohio.

The state of Ohio special specifications were followed and each phase of the pipe manufacture and installation was inspected by representatives of the state. The pipe was required to withstand 24,000# per ft. for the 0.01" crack, and 32,000# per ft. for the ultimate strength. The actual three-edge bearing test results showed the pipe passed these requirements with flying colors. The 0.01" crack did not appear until 26,000# per ft., and the ultimate was not reached until the load reached 39,200# per ft.

Produced by Price Brothers, Columbus, Ohio, the 8-foot sections of pipe with an 8½" wall of 5,000-lb. concrete, were constructed with two reinforcing cages of USS American Welded Wire Fabric. The outside cage is style 2" x 8"—0.4375" x 5 gauge and the inside cage is style 2" x 8"—0.505" x 5 gauge. More than 400 stirrups were positioned between the fabric cages for each 8-foot section to increase the resistance to diagonal tension and improve the pipe's ultimate strength.

The production of concrete pipe is closely controlled and numerous tests are conducted to assure design strength. High quality reinforcing steel is an essential ingredient for top-quality pipe. That is why USS American Welded Wire Fabric was chosen to reinforce the concrete pipe for this job. It is machine-made by electrically welding high tensile strength steel wires made to exacting specifications. The guaranteed minimum yield point is 60,000 psi and the guaranteed ultimate strength is 75,000 psi. All members are spaced to the close tolerances of plus or minus ¼" on centers. Because of the accurate machine prefabrication of USS American Welded Wire Fabric the two concentric cages can be formed faster.

Complete technical information on USS American Welded Wire Fabric is available. Just write to American Steel & Wire, Dept. 0126, 614 Superior Avenue, N.W., Cleveland 13, Ohio.

USS and American are registered trademarks

American Steel & Wire Division of United States Steel

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors
Tennessee Coal & Iron Division, Fairfield, Ala., Southern Distributors
United States Steel Export Company, Distributors Abroad

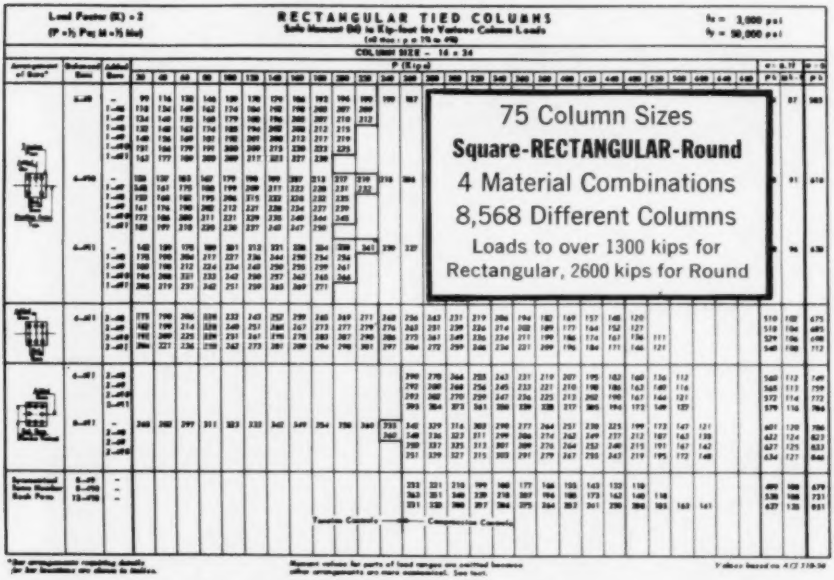
— ADVERTISEMENT —

FELIX CANDELA says:

"I have examined carefully your preliminary draft on the Ultimate Design Column Tables and have found it extremely helpful and interesting . . . I believe both professions of architect and engineer will be most grateful to you when you publish these tables."

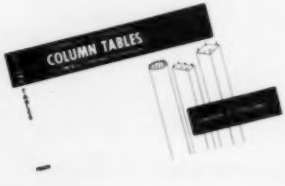
EDUARDO TORROJA says:

"I hope your book of Column Tables will enjoy the merit it deserves."


RECTANGULAR TIED COLUMNS
75 Column Sizes
Square-RECTANGULAR-Round
4 Material Combinations
8,568 Different Columns
Loads to over 1300 kips for Rectangular, 2600 kips for Round

HERE AT LAST! Your COLUMN DESIGNS COMPLETELY WORKED OUT for all combinations of loads and bending for column SIZES YOU NEED. Full benefits of Ultimate Strength design simple as A-B-C. Many PRACTICAL HELPS from start to finish of design are in this book. SAVE HOURS of design time — Get BETTER architectural and structural DESIGN.

Especially PREPARED FOR the PRACTICING ARCHITECT and ENGINEER!



order this money-saving book today

Reinforced Concrete
COLUMN TABLES
Ultimate Strength Design

$15.00 POSTPAID

No C.O.D. orders — please send check with order. If you're not completely satisfied, return the book within 10 days, and your money will be refunded.

HUGH F. FENLON
CONSULTING ENGINEER
424 MORTGAGE GUARANTEE BLDG.
ATLANTA, GEORGIA

New York engineering firm announces name change

The partners of Parsons, Brinckerhoff, Hall & MacDonald have announced a change in the firm name to Parsons, Brinckerhoff, Quade & Douglas, Engineers, with offices in New York.

AASHO Road Test starts accelerated traffic operation

The AASHO Road Test, Ottawa, Ill., has begun an accelerated traffic operation. The number of vehicles being used in the test of highway pavements and bridges is being increased by about 65 percent, and operations are being stepped up from 6 to 7 days a week.

Project officials said the move is at the request of the American Association of State Highway Officials, sponsor of the project, and was prompted by the sponsor's desire to obtain as many axle load applications as possible on the test pavements and bridges before traffic is halted next summer.

The road test is being directed by the Highway Research Board of the National Academy of Sciences–National Research Council, and financed by the states, federal government, and industry. Pavements and bridge spans of varied design are being tested under controlled truck traffic.

The test began in the fall of 1958 with a fleet of 70 commercial trucks and tractor-semitrailer vehicles. Eight tractor units were added last summer. At present, 48 additional vehicles are being put into service bringing the fleet to 118 complete truck or tractor-semitrailer vehicles plus eight spare tractor units.

Project officials said this will permit an increase from six to ten tractor-semitrailer vehicles in each of the eight traffic lanes of the four large (3.1 mile) test loops. On a smaller (1.9 mile) loop carrying light truck traffic, one lane will increase from four to six trucks and the other from eight to 12.

In addition, each traffic lane in the four large loops will have two complete tractor-semitrailers and one tractor unit on stand-by. The smaller loop will have two trucks on stand-by for each lane.

The special driver unit of the U. S. Army Transportation Corps, now stationed at the site, will continue to support the test operation. There will be no change in the daily operation pattern of two driving shifts covering about 18½ hr. The 5½-hr daily "break" is needed, officials said, for pavement and vehicle maintenance as well as certain research studies.

A tentative schedule calls for test traffic operation to halt next July 1. This will be followed by an estimated 3 months of special post-traffic tests which will include operating certain types of military vehicles on the test pavements and bridges.

Officials estimate that several more months will be required for data analysis and report writing by the Highway Research Board staff. Final close-out of all activity at the site will occur in the spring of 1961 under this schedule.

Engineers and educators confer on civil engineering education

Twenty-five of America's outstanding engineering educators and professional engineers held a 3-day conference January 9-11 to determine ways and means of bettering undergraduate curricula in civil engineering. The conference was held at Cooper Union's Green Engineering Camp, Ringwood, N.J.

Among the educational institutions represented were the Universities of California, Arkansas, Texas, Arizona, and Michigan, as well as Cornell, Columbia, Tulane, Dartmouth, Purdue, and Northwestern.

The study is being made under the sponsorship of The Cooper Union, which has received a grant of $43,410

from the National Science Foundation for the purpose. Cosponsoring the project are the American Society of Civil Engineers and American Society for Engineering Education.

Felix A. Wallace, professor of civil engineering and assistant dean of the Cooper Union School of Engineering, is directing the project. Two other conferences will be held later in the year before the group will present its recommendations according to Dr. Wallace.

ASTM holds Pacific area national meeting

No meeting in the history of the American Society for Testing Materials has been so illustrative of the society's broad scope of activity as its 3rd Pacific area national meeting held in San Francisco, in October, 1959. While emphasis in many sessions was focused on the extreme environments which materials are now required to withstand in an age of rockets, jets, missiles, re-entry nose cines, atomic power plants, and high-temperature industrial uses; other sessions were directing attention to far different but no less important problems of materials for our nation's airports, highways, dams, industrial plants, homes, and waterfront structures.

The 62 technical sessions. with five or six running concurrently throughout the week drew more than 1300.

Symposium on effect of water reducing and set-retarding admixtures

The large number of admixtures for concrete now being manufactured for a variety of purposes has led to misuse, with resulting bad effects on the concrete itself. Several speakers at the symposium emphasized that admixtures had a definite place in concrete construction when correctly used, particularly in the right amounts.

Four categories of admixtures were discussed: (1) lignosulfonic acids and their salts, (2) modifications and derivatives of lignosulfonic acids and their salts, (3) hydroxylated carboxylic acids and their salts, and (4) modifications and derivatives of hydroxylated carboxylic acids and their salts. In each, the primary component has both water-reducing and set-retarding properties, which may be modified by the addition of other components. Sugar content is a critical factor in some of the admixtures; however variation in sugar content does not appear to be important.

Data were presented to show the effect of admixtures on properties of plastic concrete such as water reduction, retardation, air entrainment, bleeding, and slump loss. The effects on hardened concrete included some increase in strength at 28 days, with a high rate of strength gain at 3 and 7 days; a substantially lower permeability to water under pressures; no appreciable reduction in volume change; some improvement in resistance to freezing and thawing; and a modest improvement in resistance to sulfate attack. It was stressed that the quantity of admixture added must be accurately measured for uniform results.

Masonry materials

Efflorescence, lightweight masonry units, and field testing of mortar and grout were discussed at the symposium on masonry materials.

The fact that efflorescence is a complex phenomenon, and that differences of opinion therefore exist on how to interpret this condition, was stressed by P. L. Rogers, Riverton Lime and Stone Co. Through the work of ASTM Committee C-12 on Mortars for Unit Masonry, and a background of research by others, a proposed method of test could now be considered by which specification limits could be set that would be tolerant enough to take care of some of the uncertainties that still exist.

The need for a field test of masonry mortar and grout was emphasized by Norman W. Kelch, Associated Brick

SELF-EXPANDING CORK

THE JOINT MATERIAL THAT "GROWS" AFTER COMPRESSION
SELF-EXPANDING CORK IN JOINT
Normal Opening
JOINT COMPRESSED
CONTRACTED JOINT
Self-Expanding Cork Filler Expands Up To 50% Beyond Original Thickness

...keeps joints filled under maximum contraction

Specify and Use Servicised SELF-EXPANDING CORK premolded joint filler in water and sewage treatment plants, canal linings and structures, outlet works, spillways and stilling basins in dams—and any other project where it is essential to keep the joints filled when contraction may open them up to more than original size.

Self-Expanding Cork Joint is formed from clean, granulated cork particles securely bonded together by an insoluble synthetic resin binder. It is specially treated to expand as much as 50% beyond original thickness. Fully compressible, non-extruding and resilient, Servicised Self-Expanding Cork is available in 1/2", 3/4" and 1" thicknesses and lengths up to 10 ft.

Write for your copy of the new Servicised Catalog. It contains complete information on Self-Expanding Cork, as well as many other types of premolded joint fillers, and the Servicised line of hot and cold applied joint sealers we manufacture. See our Catalog in Sweets.

SERVICISED PRODUCTS
CORPORATION
6051 WEST 65th STREET • CHICAGO 38, ILLINOIS

Manufacturers of Southern California. A simple method for making field test specimens of mortar and grout for reinforced grouted brick masonry was described. This method is now in use in southern California and recognized by the building code authorities.

Cement and concrete industry luncheon

A revealing description of the hyperbolic paraboloid, or more simply the umbrella type of concrete shell construction, was presented by Felix Candela of Mexico City. Mr. Candela, one of the leading proponents of reinforced concrete shell structures, was the featured speaker at the Cement and Concrete Industry Luncheon.

Radioisotope test methods

With the availability and knowledge of radioisotopes increasing every day in American industry, it is only a matter of time before ASTM adopts standards and test methods for their use. The symposium on applied radiation and radioisotope test methods was held to focus attention on several procedures using radioisotopes that might be adopted as ASTM standards.

One major problem in the cement industry is the chemical analysis for magnesium. The standard magnesium analysis takes 28 hr, most of which is needed for digestion, filtration, ignition, and weighing. The portland cement industry which depends on chemical analysis for quality control, needs a faster test. Battelle Memorial Institute has developed a procedure using the basic method but labeling the ammonium monohydrogen phosphate with phophorus-32. This enables one to make a direct determination of the amount of precipitate formed without carrying out digestion, filtration, ignition, and weighing. Using this procedure one can analyze for magnesium in less than an hour.

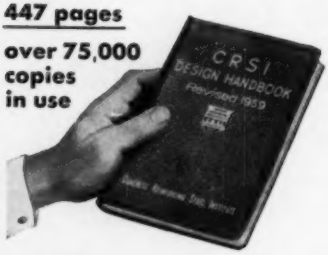
The QUICKEST way to get

REINFORCED CONCRETE DESIGNS

Revised 1959 . . . Second Edition! Third Printing!

447 pages

over 75,000 copies in use



This valuable handbook provides Reinforced Concrete Designs worked out to the latest A.C.I. Building Code. Send check or money order today for 1959 copy.

$6.00 POSTPAID

10 Day Money Back Guarantee
NO C.O.D. ORDERS

Prepared by the Committee on Engineering Practice

CONCRETE REINFORCING STEEL INSTITUTE

38 S. Dearborn St. (Div. J), Chicago 3, Illinois

Naval Civil Engineering Laboratory announces opening

Recruitment announcements from the U. S. Naval Civil Engineering Laboratory, Port Hueneme, Calif., announces openings for general engineer (GS-13) at $10,130 per year and structural engineer (GS-12) at $8810 per year.

The incumbent of the general engineer post will act as assistant division director to establish program or project schedules and to perform other management duties. As a specialist in the field of harbor and coastal engineering, the incumbent will furnish consultation and advice to personnel of the laboratory and to other Navy establishments.

Duties of the position of structural engineer, as senior project engineer, will be specifically concerned with those aspects of protective construction and passive defense operations pertaining to the loading, analysis, and design of structural systems in protective structures and passive defense matters.

Applicants should forward Standard Form 57 to Code 12C11, Placement Section, Industrial Relations Office, Construction Battalion Center, Port Hueneme, Calif.

Columbia-Southern starts production at new Ohio plant

Columbia-Southern Chemical Corp. has started cement production at its multi-million dollar electronically controlled, highly instrumented cement manufacturing facility at Barberton, Ohio. The plant features a 460-ft long rotary kiln with a diameter of 13 ft, a key unit in the installation's production capacity of 1,500,000 bbl of cement annually.

Cement produced at Barberton will be marketed in northern Ohio through Columbia Cement Corp., a Columbia-Southern subsidiary which owns and operates a cement plant at Zanesville, Ohio.

QUICK SOILS DATA for

pocket penetrometer

Thousands in use for the strength classification of cohesive soils on field exploration or construction sites and in preliminary laboratory studies.

Direct Reading Indicator maintains the Reading until reset.

PRICE $15.00 F.O.B. CHICAGO

SOILTEST Incorporated

WRITE FOR COMPLETE CATALOG

4711 W. NORTH AVE • CHICAGO 39, ILLINOIS

Bixby accepts post with ICA

Howard M. Bixby, formerly field engineer for the National Crushed Stone Association, has accepted a position with the International Cooperation Administration of the United States government.

As a project management engineer in the Transportation Division of ICA, Mr. Bixby will plan, program, and implement various highway, airfield, and waterway projects in any part of the world where the United States has a contract with a nation for technical assistance.

Mr. Bixby joined the National Crushed Stone Association in 1957 from the U.S. Bureau of Public Roads. He is a member of ACI Committee 201, Durability of Concrete in Service.

Hercules Cement appoints Griffith to key post

David P. Griffith was recently appointed vice-president in charge of operations for Hercules Cement Co., Philadelphia, a division of the American Cement Corp. Mr. Griffith joined Hercules in 1950 as plant superintendent at the Stockertown, Pa., plant.

Abruzzo appointed prestress engineer for Leschen Wire Rope

Anthony J. Abruzzo has been appointed prestress engineer for Leschen Wire Rope Division, H. K. Porter Co., Inc., St., Louis. He will be responsible for assisting producers of prestressed concrete in the eastern states with their engineering problems.

Prior to coming to Leschen, Mr. Abruzzo was active in representing the Form-Crete system of steel forms for Food Machinery and Chemical Corp. in northeastern United States and in Canada. He also has served as sales engineer for Preload Co., Inc., New York.

Great Lakes Carbon announces three sales appointments

Henry R. Richmond, formerly assistant to vice-president and division general manager D. L. Marlett, has been named general sales manager for Great Lakes Carbon Corp.'s mining and mineral products division, Los Angeles.

Appointment of two sales managers to supervise the marketing of the firm's diatomite and perlite products was also announced. Gordon G. Halvorsen will be sales manager for Dicalite filteraids and fillers while William R. Howell will be sales manager for perlite ore.

Columbia-Southern forms new cement corporation

Columbia-Southern Chemical Corp., Pittsburgh, has announced the organization of a wholly-owned subsidiary to be known as the Columbia Cement Corp.

The new corporation will own and operate the cement plant formerly owned and operated by Columbia-Southern Chemical Corp. at Zanesville, Ohio. It will also market the cement produced at Columbia-Southern's new cement installation at Barberton, Ohio.

The Zanesville plant has an annual cement capacity of 3,100,000 bbl and the Barberton installation has a capacity of 1,500,000 bbl of cement annually.

Vance, Needles, Bergendoff and Smith form new firm

Announcement has been made of the formation of the firm of Vance, Needles, Bergendoff and Smith, Limited, designing and consulting engineers, Woodstock, Ont., Canada.

The principals of the firm are James A. Vance, president, and Robert R. Smith, secretary-treasurer, together with eight partners, as individuals, of Howard, Needles, Tammen and Bergendoff, consulting engineers, New York City, and Kansas City, Mo.

Why SONOTARD was selected for New Pier 40; New York's Largest Pier now under construction

Holland-American Line, New York City
Dept. of Marine and Aviation
Vincent A. G. O'Connor, Commissioner
Capt. Lewis H. Rabbage, Chief Engineer

Roberts & Schaefer Co.—Engineers
Stock Construction Corp.—General Contractor
Corbetta-Precrete—Prestress Contractors
Colonial Sand & Stone Co.—Ready Mixed Concrete

• **SONOTARD** is being used in *all* concrete to produce consistent and uniformly high strengths required for the heavy live loads to be handled, plus voidless density to resist erosion from sea water.

• A high degree of workability to facilitate placement has been maintained through high summer heat and a winter which recorded a low mark for sustained cold weather.

• The quantities of **SONOTARD** used were varied according to temperature to keep the water content and rate of hardening constant. At all temperatures **SONOTARD** produced a uniformly high strength with maximum density and eliminated shrinkage and cracking.

• **SONOTARD** played an essential role in the prestressed deck slabs and beams by controlling the initial rate of hardening and fluidity of concrete for optimum placement properties.

• **SONOTARD** speeded the strength development (15 hours of steam cure averaged over 4500 psi) permitting early release of tension and early stripping of forms.

• Since **SONOTARD** does not increase the air content while reducing water requirements it allows the operator to control accurately the total air at all times.

Consult your local SONNEBORN representative for your particular project to learn how **SONOTARD'S** exclusive formulation can help you produce harder, denser floors—more uniform, crack resistant structures—water-tight concrete of minimum shrinkage.

SEE OUR EXHIBIT
A. C. I. NATIONAL CONVENTION,
HOTEL COMMODORE
MARCH 14—17
BOOTHS 8 AND 9

SONNEBORN CHEMICAL AND REFINING CORPORATION

Building Products Division, Dept. J40
404 Park Avenue South, New York 16, N. Y.

Precast Concrete Components Lifted and Placed with Richmond Lifting Inserts

Precast wall slab being tilted into place by means of Richmond Lifting Inserts and Lifting Brackets.

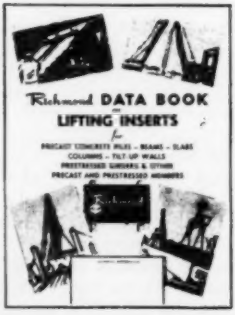
Certified tests by an independent laboratory assure proper strength rating for efficient design and performance in concrete at usable strength

Richmond has developed and tested a complete line of Lifting Inserts and accessories for handling and placing of precast concrete wall slabs, columns, beams, girders, piles, etc.

No matter what type of precast units are involved, Richmond can supply exactly the right type of insert for the specific job.

These units are designed with adequate extra strength and for simple operation in lifting and bracing precast concrete components.

Send for your copy of the Richmond Data Book on Lifting Inserts giving complete technical data, dimensions, working loads and ultimate strengths in various strengths of concrete. At the same time ask for your copy of the latest Richmond Handbook showing the complete line of form tying anchorage and accessory devices for concrete construction backed by 49 years in this field.



Richmond SCREW ANCHOR CO., INC.
INSIST ON RICHMOND
...AND BE SURE IT'S RICHMOND!

(SEE US IN BOOTH 11—A.C.I. CONVENTION)

Main Office: 816-838 LIBERTY AVE., BROOKLYN 8, N. Y.
Plants & Sales Offices: Atlanta, Georgia • Ft. Worth, Texas • St. Joseph, Missouri • **In Canada:** ACROW-RICHMOND LTD., Orangeville, Ontario.

Errata

The following corrections should be made in "Behavior and Strength in Shear of Beams and Frames without Web Reinforcement" by Roger Diaz de Cossio and Chester P. Seiss, which appeared in the February, 1960, ACI JOURNAL.

p. 697—definition of $(N/V)_x$ should read: "ratio of axial load to shear at a particular . . ."

p. 704—heading for sixth column of Table 2 should read: "Midspan steel strain* $\times$ 10^5."

* * * *

The following correction should be made in the review of "Contribution to the Stability of Cantilever Girders," on p. 427 in the Current Reviews section of the November, 1959, ACI JOURNAL:

The expression "$I_x \geqq I_y$" should read "$I_x >> I_y$."

* * * *

The following corrections should be made in "Distribution of Torsion and Bending Moments in Connected Beams and Slabs," by M. A. Gouda, which was published in the February, 1960, ACI JOURNAL.

p. 761—in the third line under the heading "Special cases," change $x = \frac{1}{2}$ to read $x = l/2$. In the formula immediately following this line and which begins "$T = m_o$ . . ." change ". . . = $m_o \cdot \frac{1}{2}$" to read ". . . = $m_o \cdot l/2$".

p. 764—in Table 2 the values 141 and 124 which are given for k should be changed to 1.41 and 1.24, respectively.

p. 767—in Eq. (14) add a minus sign to right side of equation.

p. 772—in the second equation from top of page, change ". . . $(bl/h)^2$" to read ". . . $(bl/d)^2$". First expression in Eq. (21) should read "$dm^2/dx^2 - a$ . . .".

* * * *

The following corrections should be made in "Design of Beams Subject to Torsion Related to the New Australian Code," by Henry J. Cowan, which appeared in the January, 1960, ACI JOURNAL.

p. 600—footnote should read: ". . . are obtained from the elastic and the plastic theory."

p. 603 — first expression in second equation on page should read:

$$M_{rr} = N\left(\frac{I}{\sqrt{2}} + \frac{C}{\sqrt{2}}\right) \ldots$$

p. 610—equation for area of longitudinal steel should read:

$$A_{st} = \frac{A_{sv}}{s}\ (x_1 + y_1)$$

* * * *

The following corrections should be made in "Stresses in Deep Beams," by Elihu Geer, which appeared in the January, 1960, ACI JOURNAL.

p. 654—under "Variation of stresses related to location of loads," paragraph (a) should read: ". . . in the outer thirds of the length. When load is applied only on the outer thirds of the top, tension is caused in the top fiber."

Addenda

The following acknowledgment should be added to the paper "Self-Service Parking Structures," by Richard C. Rich and William J. Rouke, which appeared in the December 1959 ACI JOURNAL.

p. 485—Acknowledgment should also be given to Nick Y. Yakovljevitch, who acted as structural consultant for Enco Engineering Co.

* * * *

The following information should be added to the review "On the Analysis of Long Cylindrical Shells," on p. 430 in the Current Reviews section of the November, 1959, ACI JOURNAL:

The discussion by G. Röntsch was printed in *Der Bauingenieur*, Mar. 1959, pp. 113-116.

* * * *

The following information on some of the speakers should be added to the story "Varied Program Featured in Mexico City" (ACI 12th Regional Meeting) in the News Letter section of the February, 1960, ACI JOURNAL.

For the paper "Stress Analysis of the Hyperbolic Paraboloid Treated as a Translational Shell," Jorge Molina Montes is with the firm Molina y

Kabeh Arquitectos and Ignacio Canals N. is a professor, Facultad de Ciencias, Universidad Nacional Automonoma de Mexico.

For the paper "The Velaria, Its Analysis and Design," Guillermo Gargollo is with Compania Cyr, SA (see above for affiliation for Ignacio Canals N.).

For the paper "Prestressed Concrete Bridge Construction in Mexico," Vicente Guerrero y Gama is with the Secretaria de Obras Publicas, Director de Proyectos y Laboratorios.

For the paper "Special Reinforcing Steel for Concrete," it was presented by Cesar Lazo Hinojosa.

For the paper "Ready-Mixed Concrete," Livio Pontecorvo is with Pre-Concreto, SA.

Winter and McGuire involved in upper atmosphere research

George Winter, head of the department of structural engineering at Cornell University, and William McGuire, associate professor of civil engineering, are engaged in the preliminary design of a powerful radar to explore the earth's upper atmosphere—the ionosphere—and surrounding space. The radar consists of a powerful transmitter, a sensitive receiving system, and an antenna larger than any now known to exist. Cornell plans to construct and operate the unit for the Defense Department in Puerto Rico.

Reginald A. Blyth

Reginald A. Blyth, owner of the R. A. Blyth Construction Co., Toronto, Ont., Canada, died recently.

Mr. Blyth entered the contracting business after graduation from the University of Toronto in 1928. While his headquarters was in Toronto, he constructed bridges, roads, and wharves from coast to coast in Canada.

The 58-year old bridge contractor left the greater part of his estate to the University of Toronto. A gift of $1,500,000 was made to the university with the stipulation that fellowships, scholarships, and bursaries in physics and mathematics be established by the trust fund.

Fred P. Diener

Fred P. Diener, director of research, Universal Atlas Cement Division of United States Steel Corp., died recently in Eastchester, N.Y.

Mr. Diener had been associated with Universal Atlas for 36 years. In the cement industry, he was considered one of the top authorities on the technology of cement and concrete uses. For many years he served as a member of ASTM Committee C-1 on Cement and as a member of the General Technical Committee of the Portland Cement Association. He was a member of a number of professional societies including ACI.

MAGNETITE AND ILMENITE

HIGH-DENSITY CONCRETE AGGREGATES
FOR
NUCLEAR SHIELDING

NUCLEAR SHIELDING SUPPLIES & SERVICE, INC.
175 Main St. White Plains, N.Y. ROckwell 1-1214

Born in Allentown, Pa., Mr. Diener was graduated from Lehigh University in 1920. After a period of chemical research work on coal concentration in the anthracite fields of Pennsylvania, he joined Universal Atlas in 1924 as special chemist at its Northampton, Pa., plant. Advancing to various posts within the organization, he was appointed director of research in 1952.

P. D. Miesenhelder

P. D. Miesenhelder, concrete research engineer for the Association of American Railroads, Chicago, died recently at the age of 64.

Mr. Miesenhelder was formerly assistant engineer of materials for the Pennsylvania Turnpike Commission and was for many years engineer of materials and tests of the Indiana State Highway Commission.

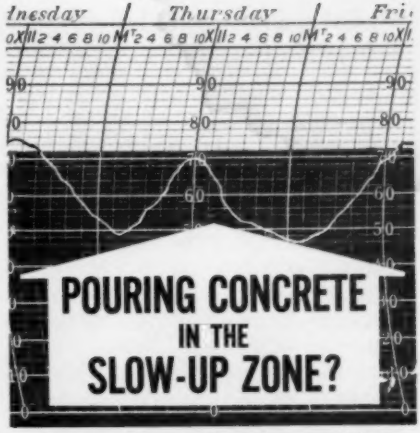
Active in Institute committee work, Mr. Miesenhelder was a member of ACI Committee 201, Durability in Service, and Committee 611, Inspection of Concrete.

Concrete drain tile manufacturers convene

The 5th annual Midwest Concrete Drain Tile Manufacturers Conference was held in the Kellogg Center at Michigan State University, East Lansing, February 23-24.

The technical program covered papers on curing concrete drain tile, general drainage specifications and installation requirements for agricultural pipe in the Midwest, and manufacturing of acid resistant concrete drain tile. Howard F. Peckworth, managing director of American Concrete Pipe Association spoke on the aims, objectives and activities of ACPA.

The conference was sponsored jointly by the Agricultural Extension Service of the university, the Michigan Concrete Drain Tile Manufacturers Association, and the American Concrete Agricultural Pipe Association.



Have your ready-mix supplier add SOLVAY CALCIUM CHLORIDE to avoid costly delays!

When temperatures vary from 70° down to 50°—it spells "SLOW-UP" which means costly delays in your concreting operations. This drop below 70° sharply decreases strength development and lengthens the waiting period before finishing.

A drop from 70° to 50°, for example, cuts 3-day strength up to 40%. To prevent this, add a low-cost 2% of SOLVAY Calcium Chloride to your concrete.

With this acceleration, concrete poured at 50° has a 3-day strength up to 40% *greater* than ordinary concrete cured at the ideal temperature of 70°!

When you use SOLVAY Calcium Chloride, you do away with overtime finishing, delays in form removal, delays between operations. You save up to 50% on protection time. And you get *better* concrete—increased in *both* early and ultimate strength—with lower water-cement ratio for more moisture-and-wear-resistant concrete.

SOLVAY® CALCIUM CHLORIDE speeds, but does not change, the basic action of portland cement. This use of calcium chloride is accepted by Portland Cement Association, Calcium Chloride Institute, leading highway departments.

Write now for full data!

Allied Chemical

SOLVAY PROCESS DIVISION
61 BROADWAY, NEW YORK 6, N.Y.
BRANCH SALES OFFICES
Boston • Charlotte • Chicago • Cincinnati
Cleveland • Detroit • Houston • New Orleans
New York • Philadelphia • Pittsburgh
St. Louis • Syracuse

RILEM symposium to be held in Haifa in July

Reunion Internationale des Laboratoires d'Essais et de Recherches sur les Materiaux et les Constructions (RILEM) will conduct a symposium on "Concrete and Reinforced Concrete in Hot Countries" in Haifa, Israel, opening on July 17 at the Israel Institute of Technology.

Rahel Shalon, chief of the Building Research Station at the Technion-Israel Institute of Technology, Haifa, is president of RILEM, and will serve as chairman of the organizing committee. E. Torroja, director of Instituto Tecnico de la Construccion y del Cemento, Costillares, Madrid, is one of several prominent European concrete authorities, arranging the program.

The technical program of the symposium will include a materials session devoted to hot weather concreting, properties of concrete, and durability. Other sessions will be based on structures, pavements and foundations, and recommendations for further research work.

Details are available from the Building Research Station, POB 4910, Haifa, Israel.

Lightweight continuous girders

Continued from p. 17

placements might make cold joints a problem, it is well to use a retarding admixture."

Credits

The late Chester L. Churchill was the architect for the Eastern Air Lines Terminal Building. The work is now under the direction of Albert C. Gray and associated architects and engineers; E. Alexander Bernhard is continuing as project architect and Edward Shaw as resident engineer. Seelye, Stevenson, Value & Knecht are the consulting engineers with H. S. Woodward as project engineer. Gilbane Building Co., Providence, R. I., is the general contractor. The ready-mixed concrete was furnished by M. F. Hickey Co., Inc., Brooklyn, N. Y.

Peninsular Portland Cement names Cox to key sales post

Grover J. Cox, formerly assistant sales director of the Peninsular Division, General Portland Cement Co., Jackson, Mich., has been named sales director of the division.

Aaron and Williams join ACPA staff

The American Concrete Pipe Association, Chicago, announces the appointment of Roy Aaron and Jack C. Williams as assistants to Howard F. Peckworth, managing director of the association.

Mr. Aaron joins the ACPA staff following 5 years employment as an associate consulting engineer with Chamlin Engineering Service of Peru, Ill. Mr. Williams has been employed for the past 4 years as a field engineer for the Structural Clay Products Institute, Ames, Iowa.

Wakeman named to concrete advisory committee

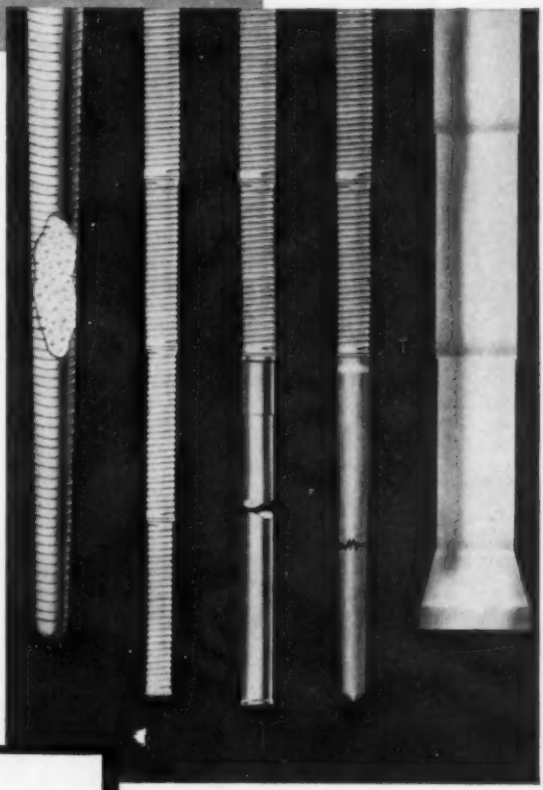
Carroll M. Wakeman, testing engineer in the Los Angeles Harbor Department, has been named a member of the advisory committee to the Long-Time Study of Cement Performance in Concrete.

The 12-member group, formed 20 years ago, is made up of the "foremost experts in cement and concrete in America," according to its parent group, the Portland Cement Association. Four members represent PCA and the cement-producing industry, and eight are drawn from important users.

Mr. Wakeman is also a member of ACI Committee, 201, Durability of Concrete in Service, and is known for his work with concrete in marine environments.

engineered for the job!

THE 5 TYPES OF RAYMOND PILES SHOWN
... from left to right
STANDARD • STEP-TAPER
PIPE STEP-TAPER
WOOD COMPOSITE • CAISSON



REGARDLESS of the subsoil conditions there's a Raymond Pile specifically designed to do the job safely and economically. The *Standard Pile* with its heavy taper is ideal as a friction pile. The *Step-Taper Pile* is used where it is desirable for the pile to reach a hard stratum at a considerable depth. The *Pipe Step-Taper Pile* is used where piles of great length are required. *Wood Composite Piles* combine the advantage of the permanence of concrete piles with the low cost of wood piles. *Raymond Gow Caissons* are efficient and economical for supporting heavy concentrated loads under certain soil conditions.

RAYMOND
CONCRETE PILE COMPANY
A DIVISION OF RAYMOND INTERNATIONAL INC.
140 CEDAR STREET, NEW YORK 6, N. Y.
Branch Offices in Principal Cities of the U. S. Subsidiaries in Canada, Central and South America and other countries around the world.

FOUNDATIONS
for the structures of America...
Complete Construction Services Abroad

Honor Roll

January 1-February 29, 1960

"Member-conscious" ACI'ers continue to add to the growth and prestige of the Institute by proposing new members. Let's keep the membership trend spiraling. Add your name to the Honor Roll next month.

Point System

1 point for Student; 2 points for Junior; 3 points for Individual; 4 points for Corporation; and 5 points for Contributing.

Alfonso Marin E. 27
Samuel Hobbs 16
Walter H. Price 9
Joaquin Spinel L. 7
Jose Luis Montemayor 6
W. S. Cottingham 5
T. C. Kavanagh 5
James A. McCarthy 5

William W. Karl 4
Joe W. Kelly 4
Henry A. Lepper, Jr. ... 4
J. E. Backstrom 3
Ira M. Beattie 3
George B. Begg, Jr. 3
Alan Carter 3
Fernando de Angulo 3
H. C. Delzell 3
Arthur Feldman 3
Benjamin P. Felix 3
Phil M. Ferguson 3
R. J. Fisk 3
Frank D. Gaus 3
Hans Gesund 3
Fabian Guerra 3
G. M. Idorn 3
Robert J. Kadala 3
Karl Kaspin 3
Clyde E. Kesler 3
E. V. Konkel 3
William J. Krefeld 3
Howard Losey, Jr. 3
John C. McCoe 3
W. J. McDonald 3
M. F. Macnaughton 3
Luis F. Magrina 3
Roman Malinowski 3
Ignacio Martin 3
W. E. Moulton 3
Poul Nerenst 3
T. Paulay 3
Russell Porter 3
Frank A. Randall, Jr. ... 3
Ilmar Reinart 3
Salvador Rodriguez 3
Howard J. Rosenberg 3
H. Rusch 3
Herbert A. Sawyer, Jr. .. 3
C. H. Scholer 3
Morris Schupack 3
H. M. Schwartz 3
Harold J. Sexton 3
M. F. A. Siddiqui 3
A. L. Small 3
George B. Southworth .. 3
F. K. Taskin 3
Pastor B. Tenchavez 3
D. A. Van Horn 3
Ellis S. Vieser 3
Cedric Willson 3
Robert P. Witt 3
Mark R. Woodward 3
Jayantilal S. Alagia 2
Arthur H. Andersen 2
Pedro M. Bassim 2
Graham Earle 2
Ward W. Engle 2
G. Grenier 2
Robert B. Harris 2
Gregorio Hernandez 2
William W. Hotaling, Jr. . 2
Fred W. Jacobs 2
I. Karni 2
Simon Lamar 2
R. R. Neal 2
Carlos Luis Nebreda 2
Carlos Isunza Ortiz 2
Raoul E. Pallais 2
Luis G. Restrepo S. 2
Walter D. Rudeen 2
E. C. Sword 2
Rogelio Bonilla Torres ... 2
Leon A. Yacoubian 2
Roger M. Zimmerman ... 2

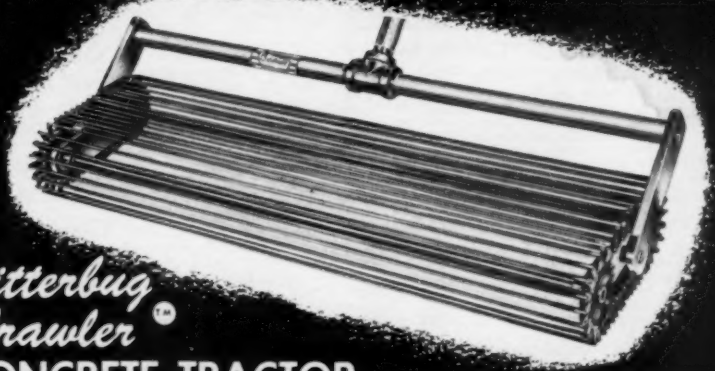
New Members

The Board of Direction approved applications in the following categories: 91 Individual, 16 Corporation, 14 Junior, and 12 Student, making a total of 133 new members. Considering losses due to deaths, resignations, and nonpayment of dues, the total membership on Jan. 1, 1960, was 10,110.

INDIVIDUAL

ANDERSEN, PAUL, Minneapolis, Minn. (Prof. of Struct. Engrg., Univ. of Minn.)
ASHFAQ AHMAD, QAZI, Madison, Wis.
ASKINS, C. B., Lake City, S. C. (Owner, C. B. Askins Co.)
BASORE, RAY E., Hulbert, Okla. (Pres., Manhattan Constr. Co.)
BORENE, ROY K., Alcova, Wyo. (Mat'ls. Engr., U.S.B.R)
BRANSTETTER, E. G., Tulsa, Okla. (Gen'l. Mgr., Rinderknecht Co.)
BRENNAN, RICHARD F., Detroit, Mich. (Pres., Brennan Co. Bldg. Constr.)
BYRAM, A. LLOYD, Beaumont, Texas (Pres., Universal Contractors Inc.)
CECCOTTI, LEE R., Corte Madera, Calif. (Pres. & Gen'l. Mgr., Ceccotti & Son of Marin, Inc.
CHEESEBROUGH, FRED W., San Francisco, Calif. (Supv. Struct. Engr.)
CHONG, YEW-CHOY, Los Angeles, Calif. (C. E., Albert C. Martin & Assocs.)
CLINCH, R. H., Salinas, Calif. (Insp. of Pub. Wks.)
COLLINS, J. E., Kirkland, Wash. (Owner, J. E. Collins & Co.)
DAVIDSON, F. H., Newark, N. J. (Vice-Pres., Igoe Bros.)
D'LAURO, FRANK A., Philadelphia, Pa.
DORIT, M. M., Mexico, D.F., Mexico
ELLIS, KENNETH K., St. Louis, Mo. (Ellis Constr. Co.)
EMERSON, R. L., South Gate, Calif. (Div. Engr., American Pipe & Constr. Co.)
ESLER, JOHN R., JR., Miami Springs, Fla. (Mat'ls. Engr., Maule Industries, Inc.)
FERNANDEZ AGUAYO, JOSE EMILIO, Mexico, D.F., Mexico (Cons. Engr.)
FICAI-VELTRONI, G., Calgary, Alta, Canada (Struct. Engr., Clayton, Bond & Mogridge)
FRANCIS, IRVING C., Williamsville, N. Y. (Gen'l. Supt., John W. Cowper Co., Inc.)
FUGLEVAND, C. WILLIAM, Havre, Mont. (Chris Fuglevand Co., Inc.)
GILBERT, WM. B., San Francisco, Calif. (C. E.)

New Concept for CONCRETE!



Jitterbug Crawler® CONCRETE TRACTOR

NO OTHER DEVICE EVER DEVELOPED FOR THE PREPARATION OF POURED CONCRETE SLABS COULD EVER MAKE

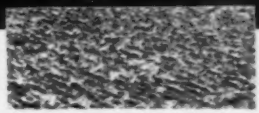
These Proven Claims . . .

- **TRACTORING MAKES WORKABLE SURFACE . . . FAST**
  Longer contact with mix puts coarse aggregate down until "fines" rise around and above.
- **TRACTORING ENDS WADING IN THE MIX**
  Because you "tamp" a large area with an easy push-pull motion, jitterbugging goes many times faster.
- **TRACTORING "LIBERATES" ONE MAN**
  Since it's so easy to use, you can use your jitterbug man for many other jobs besides tamping.
- **TRACTORING MAKES NEW TEXTURES POSSIBLE**
  New textures and new traction surfaces available without costly preparation.

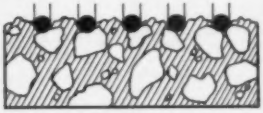
CRAWLING JITTERBUG®

CONCRETE TRACTOR MEANS BETTER CONCRETE . . . IN LESS TIME . . . AT LOWER COST!

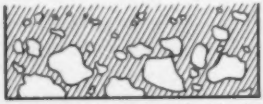
Precision engineered and fully job-proven, the Crawling Jitterbug Concrete Tractor consists of 46 parallel steel rods, each 35" across, operated by gear-driven sprocket chain. Easily operated by one unskilled man, without fluctuation in performance caused by fatigue! Completely assembled, with 12-foot sectional handle, ready to use on the job. Complete, $97.50, FOB Factory in Kansas City. Or write for FREE descriptive booklet on this sensational new machine!



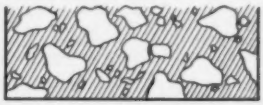
Close-up photo of Tractored surface shows how concrete Tractor's parallel bars press straight down into mix, allowing medium and fine particles to rise around them. No other method leaves surface prepared as shown in this photo!



Cross sectional diagram shows how Tractors rods "ride the rock," putting the larger aggregate just beneath surface, to improve aggregate distribution and help to create improved concrete.



Cross section of over-tamped slab shows coarse aggregate unevenly distributed and too far from surface. Such structure makes for unsatisfactory wear, as well as surface defects.



Cross section of untamped slab shows the coarse aggregate right at surface, waiting to catch blade of finishing trowel. Finished slab with this structure is more likely to spall quickly.

Goldblatt TOOL COMPANY

FREE Booklet describes new method completely—provides facts and specs on this great machine! Write for your copy, today!

1922 Walnut Street **Kansas City 41, Missouri**

PROFESSIONAL CARD

JACKSON & MORELAND, Inc.
JACKSON & MORELAND INTERNATIONAL, Inc.
Engineers and Consultants
Electrical—Mechanical—Structural
Design and Supervision of Construction for
Utility, Industrial and Atomic Projects
Surveys—Appraisals—Reports
Machine Design—Technical Publications
Boston Washington New York

GOODMAN, HERMAN, Van Nuys, Calif. (C. E.)
GRAY, ROBERT A., Chicago, Ill. (Pres., Edward Gray Corp.)
GREENFIELD, W., Winnipeg, Man., Canada (Design Engr.)
HANLEY, JOHN T., Champaign, Ill. (Res. Assoc., Univ. of Ill.)
HARBIN, JOHN E., Birmingham, Ala. (Owner, J. E. Harbin Co.)
HARRISON, DONALD L., Cape Girardeau, Mo. (Pres., D. L. Harrison Co.)
HARTMAN, JOHN S., Silsbee, Texas (Chf. Engr., East Texas Pulp & Paper Co.)
HENRY, B. C., Oakland, Calif. (Mgr., Johnson, Drake & Piper, Inc.)
HILL, G. G., Essexville, Mich. (Consumer Power Co.)
KANE, C. E., Houston, Texas (Ass't. Dist. Engr.)
KARPOWICH, GEO. A., Philadelphia, Pa. (Design Engr., Geo. F. Sook Co.)
KENERSON, W. I., East Lansing, Mich. (Owner, Kenerson Engineers)
KNOTT, EARL, St. Joseph, Mich. (Bridge Proj. Engr., Mich. State Hwy. Dept.)
KOTZE, RUPERT J., Milwaukee, Wis. (Geo. Kotze Constr. Co.)
LANKFORD, PHILLIP B., Anadarko, Okla. (Constr. Insp., U. S. B. R.)
LINDQUIST, GEORGE C., St. Paul, Minn. (Vice-Pres., Foley Bros., Inc.)
LOVERING, H., St. Paul, Minn. (C. E., Lovering Constr. Co.)
MACCLOSKY, CHARLES C., Los Angeles, Calif. (C. E., Charles MacClosky Co.)
MADSEN, GORDON, Minneapolis, Minn. (George Madsen Constr. Co., Inc.)
MARLOWE, EUGENE, Stamford, Conn. (C. E., Schupack & Zollman)
MATELICH, E. F., Kalispell, Mont. (E. F. Matelich Constr. Co.)
MCCOY, MARVIN EUGENE, Auburn, Ala. (Ala. Poly. Inst.)
MILLER, BENJAMIN, White Plains, N. Y. (Gen'l. Mgr., Carver Concrete Corp.)
MURRAY, KEVIN M., Ottawa, Ont., Canada (Conc. Insp., Warnock Hersey Co.)
MYREN, B. J., San Diego, Calif. (Mgr., Foster-Marsch Corp.)
NELSON, S. REED, Calgary, Alta., Canada (Strong Lamb & Nelson Ltd.)
ORNST, ROBERT A., Wauwatosa, Wis. (Ass't. Secy. & Treas., Selzer-Ornst Co.)
OROSZ, RUDOLPH ANDREW, Cleveland, Ohio (Floor Prods. Mgr., Acorn Paint & Chem. Co.)
PAYNE, H. N., JR., Decatur, Ga. (Engr., Wiedeman & Singleton)
PEDERSEN, STANLEY D., Fargo, N. Dak. (Constr. Engr., U. S. B. R.)
PETRABORG, GEORGE, St. Cloud, Minn. (Megarry Bros. Contractors)
PISTER, KARL S., Berkeley, Calif. (Ass't Prof. of C. E., Univ. of Calif.)
PLANT, T. C., JR., San Francisco, Calif. (Plant Bros. Corp.)
PLATT, DORAN S., JR., Washington, D. C. (Vice-Pres., Davis & Platt, Inc.)
PLEWES, WILLIAM GORDON, Ottawa, Ont., Canada (Assoc. Res. Officer, Nat'l. Res. Council)
RIVIERA VILLARREAL, RAYMUNDO, Monterrey, N. L., Mexico (C. E., Univ. of N. L.)
ROMERO JASSO, ERNESTO, Monterrey, N. L., Mexico (C. E., Univ. of N. L.)
ROSEBRAUGH, VERNON H., Manhattan, Kans. (Assoc. Prof. of C. E., Kans. State Univ.)
ROSNER, LAWRENCE M., Chicago, Ill. (Pres., Rosner Engrg. Co.)
RUHLIN, WILLIAM R., Akron, Ohio (John G. Ruhlin Constr. Co.)
SCAVONE, ANTHONY, Asheville, N. C. (Gen'l. Mgr., Asheville Conc. Mat'ls., Inc.)
SCEVA, PAUL H., JR., Spokane, Wash. (Sceva Constr. Co.)
STAMM, ROBERT J., Albuquerque, N. M. (Vice-Pres., Bradbury & Stamm)
STEELMAN, W. E., Oklahoma City, Okla. (Steelman Constr. Co.)
TEAL, EDWARD J., Los Angeles, Calif. (Ass't. Chf. Struct. Engr., A. C. Martin & Assoc.)
TOGNELLI, IVAN, San Francisco, Calif. (Vice-Pres. & Mgr., Cont'l. Service Co.)
TROAST, PAUL L., JR., Clifton, N. J. (Levenelm & Troast)
TUMBLIN, C. R., Bakersfield, Calif. (Partner, Tumblin Co.)
WEINROTH, DONALD M., Bethesda, Md. (Struct. Engr., Groll-Beach & Assocs.)
WILLSEA, FREDERICK C. J., San Francisco, Calif. (Struct. Designer, John A. Blume & Assocs.)
WISE, TERRELL E., Jackson, Miss. (Wise Constr. Co., Inc.)
ZEIGLER, WILLIAM L., Dallas, Texas
ZELMAN, M., Jasper, Alta., Canada (Resident Engr., Dept. of Public Works)
ZETTERLUND, P. A., Dallas, Texas (Chf. Engr., A. J. Boynton & Co.)
AMOS, R. C., Wellington, New Zealand
COATES, HAROLD, London S.W.1, England (Partner, L. G. Mouchel & Partners)
FAZLUL HOQUE, A. K. M., Dacca, East Pakistan (Cons. & Constr. Engr.)
GIRARDAU, R. S., MILNGAVIE nr. Glasgow, Scotland (Section Leader, G.K.N. Reinforcements Ltd.)
JENA, A. B., Bhubaneswar, India (Ass't. Engr., Gov't. of Orissa)
MARGALITH, A., Tel Aviv, Israel (Sec'y., Standards Institution of Israel)
MODLIN, SIDNEY, Brighton, Sussex, England (Chf. Struct. Engr., Kleine Co. Ltd.)
NIELSEN, ANDERS, Hellerup, Denmark (C. E.)
ROSCOE, M., Belo Horizonte, Brasil
SCHALTZ, IB SCHERMER, Hedehusene, Denmark (C.E., Nymolle Betonvarefabrik)
SHAND, NAINHAM, Cape Town, South Africa (Cons. Engr.)
SHINALY-ABELLA, B. M., Manila, Philippines (Ass't. Chf. Estimator, Atlantic Gulf & Pacific Co. of Manila, Inc.)
SIEV, AVINADAV, Haifa, Israel (Lecturer, Technion, Israel Inst. of Tech.)

CORPORATION

ALLEN BROS. CONSTRUCTION CO., Memphis, Tenn. (Morris L. Beutel, Chf. Estimator)
BYERLY CONSTRUCTION CO., Banning, Calif. (Danial A. Byerly)
F. W. CUNNINGHAM & SONS, Portland, Maine (Robert V. Cullinan, Treas.)
H. A. DAILEY, INC., St. Louis, Mo. (Chas. W. Middleton, Pres.-Treas.)
DALEY CORPORATION, San Diego, Calif. (David A. Rogers, Engr.)
FEGLES CONSTRUCTION CO., INC., Minneapolis, Minn. (W. E. Barnes, Vice-Pres.)
GILBERT & DOLAN ENTERPRISES, INC., Phoenix, Ariz. (A. Carlton Gilbert, Pres.)
ISBELL CONSTRUCTION CO., Reno, Nevada (Henry B. Isbell, Constr. Mgr.)
ROBERT E. MCKEE GENERAL CONTRACTOR, INC., El Paso, Texas (A. W. Spillman, Vice-Pres.)
OLSON CONSTRUCTION CO., Lincoln, Nebr. (J. Lyle Mehuron)

Membership in the American Concrete Institute

To facilitate prospective members in joining the Institute, membership application forms are provided. Present Members may aid by bringing these forms to the attention of those who may profit from membership advantages. All who have an interest in concrete are eligible for membership. The grades of membership are described below.

Members have at hand in Institute publications the most complete fund of knowledge on concrete. The ACI Journal provides them with the latest information and ACI special publications provide them with the complete picture of specific problems. Through conventions, and regional and area meetings, they are afforded the opportunity of meeting those whose experiences provide the new information, and of exchanging ideas with them.

ACI's world-wide membership is growing in extent and participation —traveling a common road toward better, more economical and durable concrete structures. ACI provides a common ground in the search for and use of new "working tools" in concrete design, manufacture, and erection—and its interpretation.

Individual Members (U.S. and Possessions, Canada, Mexico, Central America, and West Indies)	**$20.00**
Individual Members (All other foreign countries)	**16.00**
Corporation Members	**65.00**
Junior Members—nonvoting (under 28)	**10.00**
Contributing Members	**135.00**
Student Members—nonvoting (under 28)	**5.00**

Please enclose remittance with application (cut here)

Board of Direction, American Concrete Institute **Date**_____
P. O. Box 4754, Redford Station
Detroit 19, Michigan

The undersigned hereby applies for admission to the American Concrete Institute as ☐ *Individual* ☐ *Corporation* ☐ *Contributing* ☐ *Junior* ☐ *Student Member and agrees to be governed by the Charter and Bylaws.*

Name and complete mail address of proposed membership (Address to which Journal is to be mailed—please letter) _____

_____

For Corporation Membership, ACI representative will be _____

Date of Birth (Juniors and Students only) _____
Year Month Day

College or University attending (Students only) _____

_____ _____
(Date of graduation) (Proposed by)

Signature_____

For our records, please complete both sides of application.

NOTES on Membership Classification

The ACI advertising and editorial departments need definite information concerning job title, classification, business affiliation, and principal responsibility of all members. Thus, the information requested on the classification form below is especially important.

The applicant should designate his title or position such as: construction superintendent, research director, technician, draftsman, structural engineer, inspector, plant superintendent, highway engineer. The occupation of the applicant should be that which is **most frequently** performed. The principal responsibility of the applicant is that specific area of his job for which he is **primarily concerned.**

Classification is not based on what interests you, but on what you do—what office or job you fill. When completing the form below, please check the one item in each section that is most applicable to that particular section.

ACI editors want to know your interests—they welcome suggestions as to what you'd like to see discussed in the ACI Journal and of the possible sources. Please attach a separate note or letter.

MEMBER CLASSIFICATION

JOB TITLE _____

OCCUPATION (Check the one most applicable)

☐ Arch ☐ Engr ☐ Construction Supervision ☐ Plant Management or Supervision ☐ Teaching ☐ Student ☐ Other (please state) .....

EMPLOYER

☐ Architect ☐ Contractor ☐ Consulting Engr ☐ Engr Firm ☐ Manufacturer or Producer (specify product) .....

Government ☐ Fed ☐ State ☐ County ☐ City ☐ Educational Institution ☐ Commercial Testing Laboratory ☐ Public Utility ☐ Trade Assn ☐ Library ☐ Other (please state) .....

PRINCIPAL RESPONSIBILITY (Check the one most applicable)

☐ Design ☐ Construction ☐ Consulting ☐ Purchasing ☐ Sales ☐ Advertising ☐ Research ☐ Administrative (state position) .....

☐ Other (please state) .....

Do you ☐ Specify ☐ Authorize ☐ Recommend, purchase of materials or equipment?

A. F. Peaslee, Inc., Hartford, Conn. (A. F. Peaslee, Pres.)
J. L. Simmons Co., Inc., Chicago, Ill. (F. A. Miller, Vice-Pres.)
Standard Ready Mix Concrete, Whittier, Calif. (F. C. Horowitz, Pres.)
Stetson, Strauss & Dresselhaus, Inc., Oceanside, Calif. (Donald F. Dresselhaus, C. E., Sec'y. of Corp.)
Trinity Construction Co., Inc., Houston, Texas (F. W. Bellows, Pres.)
Virginia Lightweight Aggregate Corp., Roanoke, Va. (Beverly K. Powers, Vice-Pres.)

JUNIOR

Aktar, Atif S., Los Altos, Calif. (Engr. II, Western Knapp Engrg.)
Coston, Robert F., New Rochelle, N. Y. (Engrg. Trainee (Civil), General Foods Corp.)
Jagar, John V., Omaha, Nebr. (Engr. in Trng., Leo A. Daly Co.)
Kaspar, James M., Chicago 43, Ill. (C. E.)
MacIntosh, John D., Montreal, Que., Canada (C. E., McNamara-Key-Deschamps Const. Co.)
MacLachlan, Ian Hamilton, Montreal, Que., Canada (Foundation of Canada Engrg. Corp. Ltd.)
Marcy, Samuel Jay, Boulder, Colo. (Instructor, C. E., Univ. of Colo.)
Mutaf, Steven, E. Orange, N. J. (Struct. Engr.)
Navarro, Donald F., Mexico, D. F., Mexico (C. E., Alen S. A.)
Patel, Ramesh M., Ann Arbor, Mich. (Teach-Fellow In C. E., Univ. of Mich.)
Dan, Ravina, Haifa, Israel (Research Engr.)
Mistry, J. B., London, England (Engr., John Taylor & Sons)
Munoz Duque, Jaime, Medellin, Colombia (C. E.)
Toro Sosa, Edgar, Caracas, Venezuela (C. E.)

STUDENT

Abdulgani, Noufal Jamil, Istanbul, Turkey (Robert College)
Atasi, Hakam, New York, N. Y. (Columbia University)
Barranco, Hijo, Edelberto, Panama, Panama (Univ. of Panama)
Dagistanli, Guncor, Worcester, Mass. (Worcester Poly. Inst.)
Facchi Stroppi, Sergio, Lagunillas, Zulia, Venezuela (Univ. del Zulia)
Janus, Virginia C., Detroit, Mich. (Univ. of Detroit)
Keith, Edward J., San Francisco, Calif. (Univ. of Calif.)
Milton Canhan, Lazaro, Havana, Cuba
Pabon-Carillo, Jaime, Bogota, D.E., Colombia (Univ. Nacional)
Putnam, R. A., South Bend, Ind. (Univ. of Notre Dame)
Schapiro, Karl C., Brooklyn, N. Y. (Columbia Univ.)
Sulprizio, Paul, East Lansing, Mich. (Mich. State Univ.)

ERRATA

In the list of new members published on p. 31 of the December News Letter, listing of Tammik, Kaljo, London, England (arch.) should read: Tammik, Kaljo, London, England (Struct. Engr.)

Tools, Materials, Services

Under this heading note is made of producer literature and products of presumed technical interest to ACI users of tools, equipment, materials, accessories, and special services.

Plastic molds

Polycon plastic molds and designs for precast concrete units are now being marketed by the manufacturers of Aero forms. Wide selection of patterns and designs are available. Latest catalog describes both steel and plastic molds, forms, and accessories for all types of precast products.—Aero Form Division, Aero Welding and Mfg. Co., Inc., 800 N. Russell Ave., Aurora, Ill.

Epoxy resins

Development of six new types of epoxy resins for use in building, construction, and maintenance have been announced by Sika Chemical Corp. The compounds include joint sealants, crack sealants, bonding compound, patching compound, skid-resistant surfacing for highways, and corrosion resistant surfacing for concrete.

The epoxies are resistant to gasoline, oil, organic solvents, alkalies, and most acids according to Sika's engineers. When cured the materials will withstand temperatures up to 225 F without impairing their physical properties.—Sika Chemical Corp., 35 Gregory Ave., Passaic, N.J.

Feeder for batch plants

Fairfield Engineering Co. has announced the Fair-Flo feeder for use with batch plants and industrial applications for feeding cement, lime, fly ash, and other pulverized materials.

The unit features a 6-in. rotary serrated helix, which is driven by an air motor. The cut-off gate, a machine fit slide plate actuated by an air cylinder, closes in two stages, fully adjustable for accurate cut-off at predetermined weight according to the manufacturer. Available in 9- and 14-in. sizes.—The Fairfield Engineering Co., Marion, Ohio.

Surface protection for shell roofs

A roof treatment, Addex 480, combining asphalt-bonded glass fiber mesh with additive-treated asphalt emulsion, is said to afford a versatile roof shield offering maximum protection with minimum weight. Plasticity permits stretching in all directions—up to 15 percent—to resist normal structural stresses and movement according to the manufacturer.

Addex Color-Shield, applied by brush or spray, bonds firmly to asphalt and cures rapidly to form a white surface. Company states that Color-Shield reflects 83 percent of visible light to keep roof temperature down. The material is also applicable for covering other stress-free surfaces: asphalt shingles, brick and concrete block walls, galvanized metal, and asbestos shingles—Labco Inc., 10699 Broadway, Cleveland 25, Ohio.

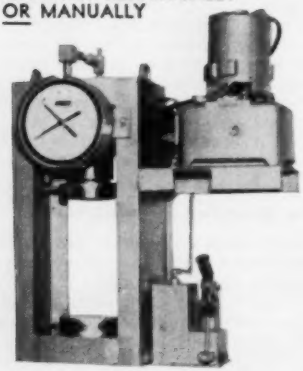
Literature Available

Pertinent details on the latest equipment and products on the market are available in recently released literature. Exact titles of the booklets and catalogs are indicated in capital letters. They may be requested directly from the manufacturers listed below.

SOILTEST ENGINEERING TESTING EQUIPMENT CATALOG—The 1960 catalog, containing 316 pp., describes over 3400 different items ranging from a small pocket sized soil penetrometer to completely equipped mobile laboratories and nuclear testing equipment. Catalog contains recommended equipment lists for specific types of testing projects.—Soiltest, Inc., 4711 W. North Ave., Chicago 39, Ill.

FORNEY
JOB-SITE CONCRETE TESTER FT 20-E

- CONFORMS TO ASTM STANDARDS
- OPERATES ELECTRICALLY OR MANUALLY



- PERMANENTLY MOUNTED ELECTRIC PUMP
- 250,000 LB. LOAD RATING FOR CYLINDERS, CORES, BLOCKS, BEAMS, CUBES, BRICK AND DRAIN TILES

FORNEY'S, INC.
TESTER DIVISION • BOX 310
NEW CASTLE, PA., U. S. A.

WHY PALLETIZE?—Informative 18-page booklet on the subject of palletizing and mechanized materials handling for mason and general building contractors. Gives a thorough description of the methods used.—American Road Equipment Co., 4201 North 26th St., Omaha, Neb.

FORD TRUCK CONCRETE MIXER APPLICATION DATA BOOK—Designed and prepared to assist ready-mixed concrete and construction companies in truck selection. Describes and illustrates the types of mixer bodies and mixer drives and outlines mixer weight distribution. Gives facts on mixer body operation, truck mixer application charts, and major mixer body specifications. Gives detailed Ford tandem specification data and construction industry truck selection guide, which gives quick reference charts for typical uses and applications—Ford Division of Ford Motor Co., P.O. Box 608, Dearborn, Mich.

PVC WATERSTOP (Bulletin No. 05-201)—Describes properties and engineering advantages of Durajoint PVC waterstops. Provides cross-sectional drawings, engineering specifications, and application details of the complete range of sizes and types available from the manufacturer—Electrovert, Inc., 124 East 46th St., New York 16, N.Y.

PUBLICATIONS OF THE IOWA ENGINEERING EXPERIMENT STATION—Lists titles of research reports published in *Bulletin* series since 1904 by the Iowa Engineering Experiment Station at Iowa State University, indicating whether or not reprints are available. Catalog also lists *Engineering Report* series.—Iowa Engineering Experiment Station, Iowa State University of Science and Technology, Ames, Iowa

WATER AND SEWAGE WORKS CONCRETE (Bulletin MBR-P5)—Discusses factors to be considered in proportioning of concrete for severe exposure conditions. Case studies of 35 installations using Pozzolith concrete are given in this 20-page publication.—The Master Builders Co., Cleveland 3, Ohio

LOUISVILLE ROTARY DRYING EQUIPMENT (Bulletin No. 59L)—Describes the design, construction, application, and general operation of Louisville rotary drying equipment. Describes facilities for study of customer problems.—General American Transportation Corp., 135 South LaSalle St., Chicago 90, Ill.

GRID SYSTEM—The Grid system of reinforced concrete construction is described. Folder contains typical safe load tables and typical layouts of ceilings and floors utilizing this construction system.—Grid Flat Slab Corp., 761 Dudley St., Boston 25, Mass.

BULLETIN BOARD

Professional Services

JACKSON & MORELAND, Inc.
JACKSON & MORELAND, INTERNATIONAL Inc.
Engineers and Consultants
Electrical—Mechanical—Structural
Design and Supervision of Construction for
Utility, Industrial and Atomic Projects
Surveys—Appraisals—Reports
Machine Design—Technical Publications
Boston Washington New York

Looking for used equipment?

. . . for qualified engineering personnel?

. . . for new business opportunities?

. . . for new clients?

Beginning with the June JOURNAL, a new classified display section . . . BULLETIN BOARD . . . will be at your service: to help you realize your needs in these areas . . . and at minimum cost.

BULLETIN BOARD announcements will be accepted in the following categories: Business Opportunities, Used Equipment, Professional Services, Positions Vacant, and Positions Wanted.

These announcements must be at least one column inch, as the Jackson & Moreland professional card shown above.
Rates per column inch are as follows:

1-2 times	3-5 times	6-9 times	10-12 times
$16.00	$15.50	$15.00	$14.50

Box numbers c/o the ACI JOURNAL will be assigned at no extra charge.

Insertions for the June BULLETIN BOARD will be accepted until April 8. No cancellations will be allowed after that date.

Your message will be read by more than 11,000 readers—contractors, engineers, architects, officers of contractor-engineering firms, engineer-trainees, government engineers, students, etc.

Send your instructions today to:

Bulletin Board **P.O. Box 4754, Redford Station**

ACI JOURNAL **Detroit 19, Mich.**

ALPHABETICAL LIST OF ADVERTISERS

(Page Numbers refer to News Letter)

American Steel & Wire Division, United States Steel 24-25
Colorado Fuel and Iron Corporation—Clinton Welded Wire Fabric 18
Columbia-Southern Chemical Corporation 8
Concrete Reinforcing Steel Institute 6, 30
Hugh F. Fenlon 26
Forney's, Inc. 46
Goldblatt Tool Company 41
Jackson & Moreland, Inc. 42
Lehigh Portland Cement Company 13
Lone Star Cement Corporation ..... Inside Front Cover
Master Builders Company, The; Division of American-Marietta Co. 21
Nuclear Shielding Supplies & Service, Inc. 36
Presstite Division, American-Marietta Company 14
Rail Steel Bar Association 22
Raymond Concrete Pile Company 39
Richmond Screw Anchor Co., Inc. 34
Servicised Products Corporation 29
Sika Chemical Corporation ..... iv (flyleaf)
Soiltest, Inc. 31
Solvay Process Division, Allied Chemical Corporation 37
Sonneborn Chemical and Refining Corporation, Building Products Division 33

The Institute assumes no responsibility for the claims of advertisers. The advertiser is made responsible in the belief that his place in the field will be determined by the public's ultimate measure of his exercise of that responsibility.

NOTICE — Change of Address — NOTICE

To avert any delay in receiving my ACI JOURNAL, I wish to give notice of a change in my mailing address. (PLEASE PRINT)

New Address:

NAME_____

STREET & NO. _____

CITY_____ ZONE____ STATE_____

Old Address:

STREET & NO. _____

CITY_____ ZONE____ STATE_____

DISCUSSION

Disc. 56-1 **Recommended Practice for Hot Weather Concreting (ACI 605-59),** ACI Committee 605 907

Disc. 56-4 **Effect of Bar Cutoff on Bond and Shear Strength of Reinforced Concrete Beams,** Phil M. Ferguson and Farid N. Matloob 911

Disc. 56-5 **Prestressed Overlay Slab for San Antonio Airport,** M. M. Lemcoe and C. H. Mahla 919

Disc. 56-6 **Properties of Nuclear Shielding Concrete,** James O. Henrie 923

Disc. 56-7 **Width of Cracks in Concrete at the Surface of Reinforcing Steel Evaluated by Means of Tensile Bond Specimens,** David Watstein and Robert G. Mathey 929

Disc. 56-9 **Surface Cooling of Mass Concrete to Prevent Cracking,** Roy W. Carlson and Donald P. Thayer 931

Disc. 56-10 **Folded Plate Raft Foundation for 24-Story Building,** Ignacio Martin and Sixto Ruiz 949

Disc. 56-11 **General Elastic Analysis of Flat Slabs and Plates,** John F. Brotchie 951

Disc. 56-13 **Creep Recovery of Mortars Made with Different Cements,** A. M. Neville 953

Disc. 56-14 **Lateral Stability of Reinforced Concrete Beams,** William Hansell and George Winter 957

Disc. 56-15 **Chicago's 39-Story R/C Executive House,** Henry Miller 969

Disc. 56-16 **Laboratory Study of Pavements Continuously Reinforced with Deformed Bars,** Martin J. Gutzwiller and Joseph L. Waling 975

1960 ANNUAL MEETING — NEW YORK CITY — March 14-17

THIS MONTH

Papers and Reports 825-880

56-45 **Long-Time Study of Cement Performance in Concrete. Chapter 12—Concrete Exposed to Sea Water and Fresh Water** I. L. TYLER 825

56-46 **Yield Moments of Reinforced Concrete Beams and Columns** CLARENCE W. DUNHAM and HANS GESUND 837

56-47 **Effects of Incomplete Consolidation on Compressive and Flexural Strength, Ultrasonic Pulse Velocity, and Dynamic Modulus of Elasticity of Concrete** ..... M. F. KAPLAN 853

56-48 **Bearing Capacity of Concrete Blocks** ..... TUNG AU and DONALD L. BAIRD 869

Concrete Briefs 881-890

Current Reviews 891-904

Discussion 905-984

Discussion contents listed on inside back cover

News Letter 1-48